PREFACE

This booklet **"Experimental Skills"** is specifically tailored to meet the needs of aspiring medical students preparing for the National Eligibility cum Entrance Test (NEET) in accordance with the latest syllabus with a purpose to development of knowledge and interest in the fundamental skills required for experimental physics.

We understand that NEET aspirants are not only expected to excel in the biological sciences but also possess a strong foundation in physics, including the ability to conduct experiments which further add the value to their future profession. In the pages that follow, you will find a comprehensive and easy-to- understand guide that covers the critical aspects of experimental physics, geared towards the latest NEET syllabus. We aim to assist you in developing a solid grasp of the experimental methodologies and principles that will be an integral part of your performance in the physics section of the NEET exam.

Whether you are a dedicated NEET aspirant looking to secure a future in medical science or an enthusiastic student eager to build a strong foundation in physics, this booklet offers you the necessary resources to master the art of experimental physics. By studying the contents of this book, you will not only excel in your NEET examination but also gain valuable skills that can serve you throughout your future scientific career.

So, let's embark on this enlightening journey together as we delve into the intricacies of experimental physics and empower you to excel in your NEET aspirations and beyond.

EXPERIMENTAL SKILLS

IMPORTANT NOTES

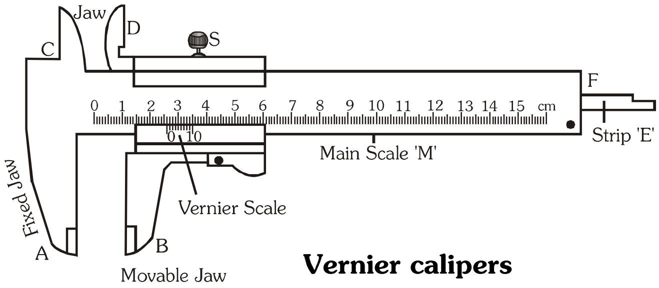
VERNIER CALIPERS-ITS USE TO MEASURE THE INTERNAL AND EXTERNAL DIAMETER AND DEPTH OF A VESSEL

Introduction about vernier calipers :

It is a device, designed by a French Mathematician Pierre Vernier to measure accurately upto $\left(\frac{1}{10}\right)$th of a millimetre.

It has four parts :-

(i) Main scale (ii) Jaws (internal and external) (iii) Vernier scale (iv) Metallic strip



Vernier calipers

Main Scale :

It is a steel metallic strip M with fixed jaws as shown in figure, graduated in cm and mm on one edge and inches on other side which is not shown in the figure.

Jaws :

It has two fixed jaws A and C and two movable jaws B and D as shown in the figure. Jaws A and B are to measure thickness or length and C & D to measure internal diameter of vessel. When jaws A and B are closed, straight part of C and D jaws also touch each other.

Vernier Scale :

Vernier scale slides freely left or right on metallic strip M. It can not only slide but also be fixed in any position by screw S. In laboratory vernier calliper, vernier scale has 10 divisions which coincide with 9 mm of main scale.

Note : In questions it is not necessary that 9 main scale divisions coincide with 10 vernier scale division you will get information about this in question.

Metallic Strip :

A metalstrip E attached to back side of M and connected with vernier scale. When jaws A and B touch each other, the edge of E touches the edge M. The strip E is used for measuring depth of vessels.

Vernier Constant or Least count :

The smallest measurement possible with vernier calipers is called **vernier constant** or Least count..

or

The smallest value of a physical quantity which can be measured (accurately) with an instrument is called the least count (L.C.) of the measuring instrument.

or

Vernier Constant (V.C.) is defined as the difference between one main scale division (MSD) and one vernier scale division (VSD).

V.C. = 1 MSD. – 1 VSD

Now suppose the size of one main scale division is **M** units and that of one vernier scale division is V units. Also suppose that the length interval of **b** vernier divisions is equal to the length interval of **a** main scale divisions.

i.e. $aM = bV$

$$V = \frac{a}{b}M$$

or $\therefore$ V.C. or L.C. $= M - V = M - \frac{a}{b}M = \left(\frac{b-a}{b}\right)M$

Example :- A vernier scale contains 10 equal divisions. These 10 divisions (each of length V units) coincide with 9 equal divisions (each of the length S units) of the main scale. The length of one small division on the main scale is 1 mm, i.e., S = 1 mm. then calculate vernier constant.

Thus, $10\text{ V} = 9\text{S}$

or $V = \frac{9}{10}S$ $\qquad \therefore$ $(S - V) = S - \frac{9}{10}S$

or $(S–V) = \left(1-\frac{9}{10}\right)S = \frac{1}{10}S$ $\qquad$ But $S = 1$ mm

$\therefore$ $(S–V) = \frac{1}{10}$ mm $\qquad$ or vernier constant,

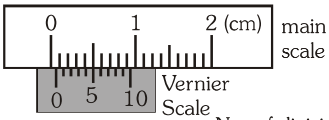
$$\text{V.C.} = \frac{1}{10}\text{mm} = 0.1 \text{ mm} = 0.01 \text{ cm}$$

Zero Error and its Types :

Due to wear and tear of the jaws by some manufacturing defect, the zero marks of the main scale and vernier scale may not be in the same straight line, when the jaws A & B are made to touch each other. This error is known as zero error. It can be positive or negative.

1. Positive error :

The zero error is positive when the zero mark of the vernier scale lies towards the right side of the zero of the main scale (figure).

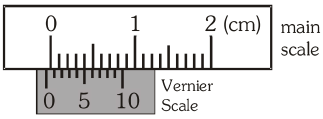


Positive Error = $\frac{\text{No. of division of VS coincided with MS}}{}$ $\times$(L.C)

$= (5)\ (0.1 \text{ mm}) = 0.5 \text{ mm or } 0.05 \text{ cm}$

2. Negative error

When the zero mark of the vernier scale lies towards the left side of the zero of the main scale (figure), then the zero error is called negative error.



Negative Error = –[Total no. of VSD – VSD coinciding with main scale] $\times$(L.C.)

$= -[10 - 5] \times (0.1 \text{ mm}) = -0.5 \text{ mm or } -0.05 \text{ cm}$

Correction of zero error :

To get the correct reading, zero error with proper sign is subtracted from the observed reading.

Means : Actual reading = observed reading – zero error

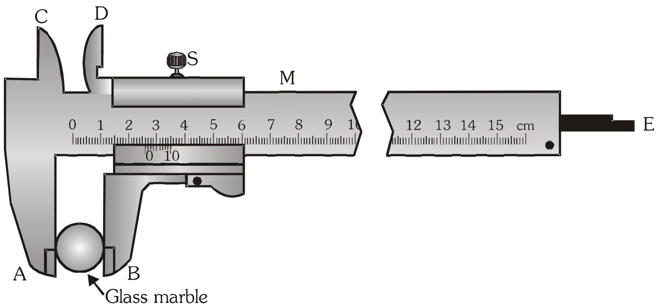
EXPERIMENT # 1

Objective :- Use of vernier calipers to measure internal and external diameter and depth of a vessel.

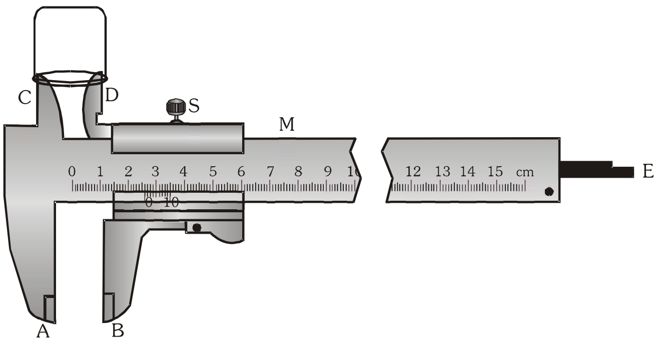
Apparatus required :-Vernier calipers, convex lens and a cylindrical vessel whose external or internal diameter or depth is to be measured.

Procedure :

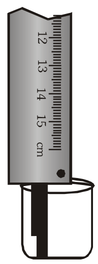
1. First, determine the least count and zero error of a given vernier calipers.
2. Now, to measure thickness or diameter or length of the body, fix the body between the lower jaws A and B of the vernier calipers and tighten the screw S (figure).



3. To measure the internal diameter of a cylindrical vessel such as calorimeter, insert the upper jaws C and D of vernier calipers in the given vessel (figure). Open the jaws to the extent that their edges touch the internal walls of the vessel.



4. To measure the depth of a given vessel, hold the edge of the vernier calipers at the ring of the vessel and move the vernier scale in such a direction so that strip E attached to it, just touches the bottom of the given vessel (figure). Clamp the vernier scale with the help of screw S.



In all the above cases : TG: @NEETxNOAH

1. Find LC of the instrument.
2. First of all observe zero error as shown above.
3. Now put object between jaws and lock its position with screw.
4. Observe the main scale reading (MSR).
5. Observe the vernier scale division coinciding with MSD $\Rightarrow$ (VSR).
6. Observed reading = MSR + (VSR) $\times$(L.C)
7. Correct reading = measured reading – zero error

   = MSR + (VSR) $\times$(L.C) – zero error

Precautions:

1. Motion of vernier scale on main scale should be made smooth (by oiling if necessary).
2. Vernier constant and zero error should be carefully observed and properly recorded.
3. The body should be gripped between the jaws firmly but gently (without undue pressure on it from the jaws).
4. Observations should be taken at right angle at one place and taken at least at three different places.

Sources of error :

1. The vernier scale may be loose on main scale.
2. The jaws may not be at right angles on the mains scale.
3. The graduations on scale not be correct and clear.

Special points :

Different type of vernier scales are available now a days, in which some of these are :-

1. Ordinarily in Laboratory

We use vernier calipers in which 10 VSD coincide with 9 MSD and main scale has 10 divisions in 1 cm.

Therefore, 1 MSD = $\frac{1}{10}$ cm and N = 10 (N = No. of VSD)

Thus $\quad V.C.=\frac{1MSD}{N}=\frac{1}{10}\times\frac{1}{10}cm=0.01cm=0.1mm$

2. In Fortin's Barometer

1 cm on main scale is divided into 20 divisions. Also 25 divisions of Vernier scale coincide with 24 divisions of main scale.

$$V.C.=\frac{1MSD}{N}=\frac{1}{20}\times\frac{1}{25}cm=0.002cm.=0.02mm$$

3. In Travelling Microscope :

1 cm on main scale = 20 divisions.

$$1\ MSD = \frac{1}{20}\ cm.$$

50 vernier divisions coincide with 49 divisions on main scale.

So $\quad N = 50$

$\therefore \quad V.C.=\frac{1MSD}{N}=\frac{1}{20}\times\frac{1}{50}=\frac{1}{1000}cm=0.001cm$

MULTIPLE CHOICE QUESTIONS

1. Vernier Calipers is provided with :-

(1) Jaws to measure external diameter
(2) Jaws to measure internal diameter
(3) Strip to measure depth of hole
(4) All of above

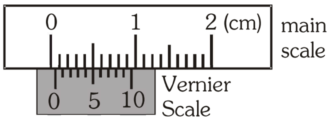
2. Vernier calipers cannot be used to measure :-

(1) External diameter of a cylinder
(2) Internal diameter of a cylinder
(3) Diameter of a pin point
(4) Length of a pin

3. What is the function of upper pair of jaws in the vernier calipers ?

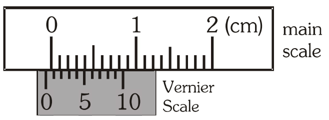
(1) To measure internal diameter of vessel
(2) To measure external diameter of vessel
(3) To measure depth of vessel
(4) None of these

4. The figure shows a vernier (whose least count = 0.1 mm) with jaws of vernier are touching each other. The zero error in the vernier calliper is :-



(1) + 0.5 mm (2) – 0.5 mm
(3) + 0.5 cm (4) – 0.5 cm

5. The figure shows a situation when the jaws of vernier are touching each other. If least count of vernier is 0.1 mm, the zero error in the vernier calliper is :-



(1) + 0.5 mm (2) – 0.5 mm
(3) + 0.3 mm (4) – 0.3 mm

6. What is vernier constant ?

(1) It is the value of the one main scale division by the total number of divisions on the main scale.
(2) It is the value of one vernier scale division divided by the total number of division on the vernier scale.
(3) It is the difference between value of one main scale division and one vernier scale division
(4) It is not the least count of vernier scale

7. If size of one main scale division is S units and size of one vernier scale division V units and 'm' vernier scale divisions coincide with (m – 1) divisions on main scale then :-

(1) $S - V = \frac{S}{m-1}$ (2) $S - V = \frac{m}{S}$
(3) $S - V = \frac{S}{m}$ (4) None of these

8. The vernier scale of vernier calipers has 10 divisions. One centimetre on the main scale is divided into ten equal parts. If 10 divisions of the vernier scale coincide with 8 small divisions of the main scale, the least count of the calipers is:-

(1) 0.01 cm (2) 0.02 cm
(3) 0.05 cm (4) 0.005 cm

9. In a vernier calipers smallest division of main scale is 1 mm. Vernier scale has 20 divisions which coincide with 19 divisions of main scale. When fixed jaw touches a movable jaw, zero of vernier scale lies on right of zero of the main scale and 12th division of vernier scale coincides with any division of main scale. Type of zero error and its value is :-

(1) + ve, 0.60 mm (2) – ve, 0.60 mm
(3) + ve, 0.6 mm (4) – ve, 0.6 mm

10. The main scale of vernier calipers is divided into 0.5 mm and its least count is to be 0.005 cm. The number of vernier divisions is :-

(1) 10 (2) 20 (3) 30 (4) 40

11. To measure the length of a cylinder, a student uses the vernier calipers, whose main scale reads atleast 1 mm and its vernier is divided into 10 divisions which coincide with 9 divisions of the main scale. He observed that when the two jaws of the instrument touch each other the eighth division of the vernier scale coincides with any one of the main scale division and the zero of the vernier lies to the right of the zero of main scale. When he placed a cylinder tightly along its length between the two jaws the zero of the vernier scale lies slightly to the left of 42 mm and the fourth vernier division coincides with a scale division. The length of the cylinder measured by the student is :-

(1) 4.14 cm 2) 4.24 cm
(3) 4.06 cm (4) 4.32 cm

12. The length of a cylinder is measured with the help of a vernier calipers whose nine divisions of the main scale are equal to ten divisions of the vernier scale. Smallest division on the main scale is 0.5 mm. It is observed that zero of vernier scale has just crossed the 78th division of the main scale and its fourth division coincides with any main scale division. The length of the cylinder is :-

(1) 78.4 mm (2) 39.40 mm
(3) 39.4 mm (4) 39.20 mm

Passage :

A vernier calipers used by student has 20 divisions in 1 cm on main scale. 10 vernier divisions coincide with 9 main scale divisions. When jaws are closed, zero of main scale is on left of zero of vernier scale and 6th division of vernier scale coincides with any of main scale divisions. He places a wooden cylinder in between the jaws and measure on length. The zero of vernier scale is on right of 3.20 cm and 8th vernier division coincides with any main scale division. When he measures thickness of cylinder he finds that zero of vernier scale lies on right of 1.50 cm mark of main scale and 6th division of vernier scale coincides with any main scale division. From above observations answer the following questions.

13. Least count and zero error of vernier calipers are:-

(1) 0.05 cm, + 0.30 cm
(2) 0.05 mm, + 0.30 mm
(3) 0.05 mm, – 0.30 mm
(4) 0.05 cm, – 0.30 cm

14 Correct values of measured length and diameter are :-

(1) 3.21 cm, 1.50 cm
(2) 3.210 cm, 1.500 cm
(3) 3.27 cm, 1.93 cm
(4) 3.270 cm, 1.560 cm

15. In an experiment the angles are required to be measured using an instrument, 29 divisions of the main scale exactly coincide with the 30 divisions of the vernier scale. If the smallest division of the main scale is half-a-degree (=0.5°), then the least count of the instrument is :-

(1) One degree (2) Half degree
(3) One minute (4) Half minute

16. N divisions on the main scale of a vernier calipers coincide with (N + 1) divisions of the vernier, scale. If each division of main scale is 'a' units, then the least count of the instrument is :-

(1) $\frac{a}{N}$ (2) $\frac{N}{N+1}\times a$
(3) a (4) $\frac{a}{N+1}$

17. A vernier calipers having 1 main scale division = 0.1 cm is designed to have a least count of 0.02 cm. If n be the number of divisions on vernier scale and m be the length of vernier scale, then :-

(1) n = 10, m = 0.5 cm
(2) n = 9, m = 0.4 cm
(3) n = 10, m = 0.8 cm
(4) n = 10, m = 0.2 cm

18. The vernier of a circular scale is divided in to 30 divisions, which coincides with 29 main scale divisions. If each main scale division is $(1/2)^{\circ}$, the least count of the instrument is

(1) 0.1' (2) 1'
(3) 10' (4) 30'

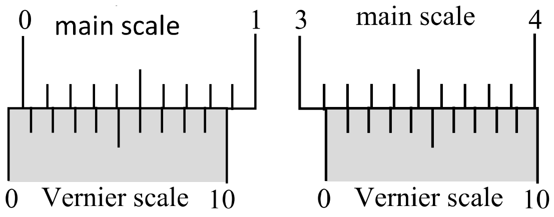
19. The least count of the main scale of a vernier calipers is 1 mm. Its vernier scale is divided into 10 divisions and coincide with 9 divisions of the main scale. When jaws are touching each other, the 7^{th} division of vernier scale coincides with a division of main scale and the zero of vernier scale is lying right side of the zero of main scale. When this vernier is used to measure length of a cylinder the zero of the vernier scale between 3.1 cm and 3.2 cm and 4^{th} VSD coincides with a main scale division. The length of the cylinder is : (VSD is vernier scale division)

(1) 3.21 cm (2) 2.99 cm
(3) 3.2 cm (4) 3.07 cm

20. The diameter of a cylinder is measured using a Vernier calipers with no zero error. It is found that the zero of the Vernier scale lies between 5.10 cm and 5.15 cm of the main scale. The Vernier scale has 50 divisions equivalent to 2.45 cm. The 24^{th} division of the Vernier scale excatly coincides with one of the main scale divisions. The diameter of the cylinder is :-

(1) 5.112 cm (2) 5.124 cm
(3) 5.136 cm (4) 5.148 cm

21. The smallest division on the main scale of a Vernier calipers is 0.1 cm. Ten divisions of the Vernier scale correspond to nine divisions of the main scale. The figure below on the left shows the reading of this calipers with no gap between its two jaws. The figure on the right shows the reading with a solid sphere held between the jaws. The correct diameter of the sphere is



(1) 3.07 cm (2) 3.11 cm

(3) 3.15 cm (4) 3.17 cm

ANSWER KEY

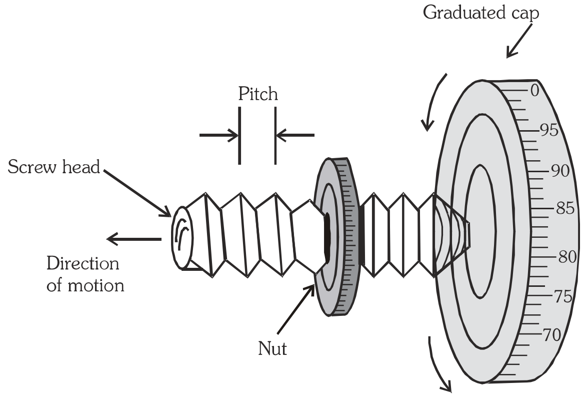
Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	**4**	**3**	**1**	**1**	**2**	**3**	**3**	**2**	**1**	**1**	**3**	**4**	**2**	**2**	**3**
Que.	16	17	18	19	20	21									
Ans.	**4**	**3**	**2**	**4**	**2**	**3**									

SCREW GAUGE-ITS USE TO DETERMINE THICKNESS/ DIAMETER OF THIN SHEET/WIRE

Concept of Screw gauge or Spherometer :

When a screw, fitted in a nut is rotated in any direction, it rotates about the axis as well as translates along the axis. In this motion linear distance moved by the screw head is directly proportional to the amount of rotation given to the screw.

The linear distance moved by the screw along its axis in one complete rotation is called pitch. It is also equal to the distance between the two successive threads on the screw (figure).



Least Count :

For a screw, it is defined as the ratio of the pitch to the total number of divisions made on the circular cap/scale as shown in above figure.

$$\text{Least count} = \frac{\text{pitch}}{\text{total number of divisions on the circular scale}}$$

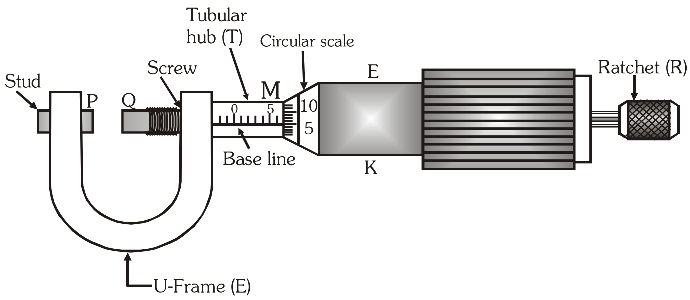
Now, suppose the circular scale is divided into 100 equal parts and the pitch of the screw is 1mm, then

$$\text{Least count} = \frac{1\text{mm}}{100} = 0.01 \text{ mm or } 0.001 \text{ cm or } 10\ \mu\text{m}$$

Because the least count of the screw is in the order of micrometer, therefore it is also known as micrometer screw. The screw gauge/micrometer and spherometer are based on the principle of screw.

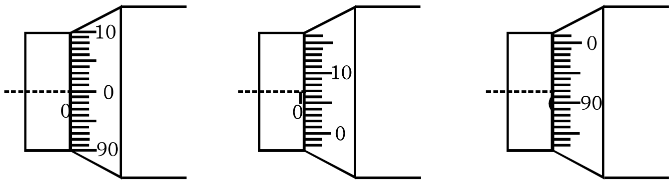
Introduction of the screw gauge :

It consists of a U-shaped frame E of gunmetal. At one end of E, a small metal piece P having a plane face is attached. It is called the stud. At right angles to the other end of E is fixed the tubular hub T. The inner side of T is threaded and has a screw of gun metal having its front face Q as plane. Gun metal is used because, it has very less wear and tear.



The tubular hub T extends a few centimeters beyond the end of the frame. The extended portion is graduated in millimeters. This is known as pitch scale or the main scale M. It has a base line which lies along the axis of the hub. This base line is known as line of cylindrical graduation. A hollow cylindrical cap is fixed to the right hand end of the screw. Q. This cylindrical cap can feeely rotate about the hub T. Thus one can easily move the screw Q in and out. The circular cap is generally divided into 100 or 50 equal parts. It is called the circular scale or the head scale. A ratchet R is fixed to the right hand end of the cap. This ratchet avoids undue tightening of the screw and starts giving cracking sound when heads P and Q meet each other.

Zero error :



No zero error **(Fig. A)** Positive zero error **(Fig. B)** Negative zero error **(Fig. C)**

If zero of circular scale does not coincide with zero of linear scale when heads P and Q touch each other, the screw gauge is said to have zero error. It is also of two types :

1. Positive Zero Error :

If zero of circular scale has not crossed the base line on linear scale then zero error of the screw is positive as shown in figure B.

2. Negative Zero Error :

If zero of the circular scale has crossed the base line of linear scale then zero error of the screw is negative as shown in figure C.

Back lash error :

This error is caused due to loose fitting of screw in threads of hub. This may be caused by long use of screw causing wear and tear of threads. In such screw gauge, if we suddenly change the sense of rotation, the screw head may rotate without actual motion of the screw. This error can be minimized by rotating the screw in same sense for same set of observations.

EXPERIMENT

Objective :- Screw gauge- use to determine thickness/ diameter of thin sheet/wire.

Apparatus required :- screw gauge, thin wire, convex lens etc.

Procedure :

1. First of all observe zero error as shown above, in figure B or C & find LC of instrument.
2. Put the wire between heads P and Q of screw gauge and closed the jaws till there is cracking sound of ratchet.
3. Observe reading on main scale say it is MSR.
4. Observe the division on circular scale which is in line with the base line, say it is CSR.
5. Observed value = MSR + CSR $\times$LC
6. Corrected value = observed value – (zero error) = MSR + (CSR) $\times$(L.C.) – Zero error

Precautions :

1. To avoid undue pressure, the screw gauge always be rotated by rachet and not by cap.
2. The screw should move freely without friction.
3. The zero correction, with proper sign should be noted very carefully and added carefully.
4. For same set of observations, the screw should be moved in the same direction to avoid back lash error of the screw.
5. At each point, the diameter of the wire should be measured in two perpendicular directions and then the mean of the two be taken.
6. Reading should be taken at least for five different places equally spaced along the whole length of the wire.

Sources of Error :

1. The screw may have friction.
2. The screw gauge may have back-lash error.
3. Circular scale divisions may not be equal in size.
4. The wire may not be uniform.

MULTIPLE CHOICE QUESTIONS

1. The incorrect statement is :-

(1) The least count of screw gauge depends only on the number of circular scale divisions.

(2) In a positive zero error, the zero of circular scale lies below the reference line

(3) In a positive zero error, the zero of the main scale is visible

(4) The screw gauge with a pitch of 0.5 mm is more precise than the instruments with a pitch of 1 mm if both have the same number of circular divisions.

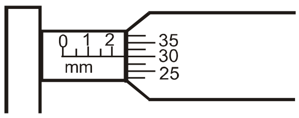
2. For the pitch of a screw 0.1 cm and 200 divisions on circular scale, the least count will be:-

(1) 0.5 mm (2) 0.05 mm
(3) 0.005 mm (4) 0.0005 mm

3. The screw gauge has least count of 0.005 mm and its circular scale is divided into 100 equal divisions. What is the distance between two consecutive threads of its screw ?

(1) 0.5 mm (2) 0.05 mm
(3) 0.01 mm (4) 0.1 mm

4. What is the reading of micrometer screw gauge shown in figure (no. of divisions on circular scale is 50):-



(1) 2.30 mm (2) 2.29 mm
(3) 2.36 mm (4) 2.41 mm

5. The pitch of a screw gauge is 1mm and there are 100 divisions on its circular scale. During the process of finding the zero error, a student finds that the zero of the circular scale lies 4 divisions below the reference line. When an experimental steel wire is placed between the studs, two main scale divisions are clearly visible and 57 divisions on the circular scale are observed. The diameter of the wire is :-

(1) 2.53 mm (2) 2.61 mm
(3) 2.57 mm (4) 2.63 mm

6. The pitch of a screw gauge is l mm and there are 50 divisions on its cap. When nothing is put in between the studs, 44th division of the circular scale coincides with the reference line and zero of the main scale is not visible. When a glass plate is placed between the studs, the main scale reads three divisions and the circular scale reads 26 divisions. Calculate the thickness of the plate.

(1) 3.64 mm (2) 2.64 mm
(3) 2.64 cm (4) 3.64 cm

Comprehension based questions

Passage-I :

Pitch of screw gauge is 0.5 mm. Circular scale has 250 divisions. While measuring the diameter of a wire the linear scale reads 15 divisions and 100 divisions coincides with reference line of linear scale.

7. The least count of the screw gauge is :-

(1) 0.005 mm (2) 0.0025 mm
(3) 0.100 mm (4) 0.002 mm

8. The observed value of diameter of the wire is :-

(1) 7.7 mm (2) 7.700 mm
(3) 7.70 mm (4) 0.770 mm

Passage-II :

In a screw gauge, pitch is 1 mm and circular scale has 100 divisions. When nothing is put between the jaws A and B which just closed then 13 divisions of circular scale are below the zero of reference line on linear or main scale. When a wire is placed between the jaws two linear scale divisions are clearly visible while 73 divisions on circular scale coincide with reference line.

9. The zero error is :-

(1) + 0.13 mm
(2) + 1.30 mm
(3) – 0.13 mm
(4) –1.30 mm

10. The observed value of diameter of the wire is :-

(1) 2.73 mm (2) 2.86 mm
(3) 2.60 mm (4) 2.730 mm

11. Actual thickness of wire is :-

(1) 2.73 mm (2) 2.86 mm
(3) 2.60 mm (4) 2.730 mm

12. Two full turns of the circular scale of screw gauge cover a distance of 1 mm on scale. The total number of divisions on circular scale is 50. Further, it is found that screw gauge has a zero error of -0.03 mm. While measuring the diameter of a thin wire a student notes the main scale reading of 3 mm and the number of circular scale division in line, with the main scale is 35. The diameter of the wire is :-

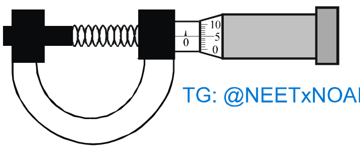
(1) 3.32 mm (2) 3.73 mm
(3) 3.67 mm (4) 3.38 mm

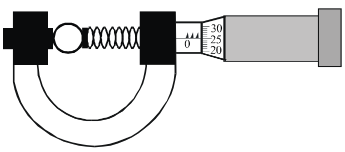
13. A screw gauge gives the following reading when used to measure the diameter of a wire.
Main scale reading : 0 mm.
Circular scale reading : 52 divisions
Given that 1 mm on main scale corresponds to 100 divisions of the circular scale.
The diameter of wire from the above date is :-
(1) 0.026 cm (2) 0.005 cm
(3) 0.52 cm (4) 0.052 cm

14. A screw gauge with a pitch of 0.5 mm and a circular scale with 50 divisions is used to measure the thickness of a thin sheet of Aluminium. Before starting the measurement, it is found that when the anvil and screw are in contact with each other, the 45^{th} division coincides with the main scale line and that the zero of the main scale is barely visible. What is the thickness of the sheet if the main scale reading is 0.5 mm and the 25^{th} division coincides with the main scale line ?
(1) 0.50 mm (2) 0.75 mm
(3) 0.80 mm (4) 0.70 mm

15. When the gap is closed without placing any object in the screw gauge whose least count is 0.005 mm, the 5^{th} division on its circular scale coincides with the reference line on main scale, and when a small sphere is placed reading on main scale advances by 4 divisions, whereas circular scale reading advances to five times to the corresponding reading when no object was placed. There are 200 divisions on the circular scale. The radius of the sphere is
(1) 4.10 mm (2) 4.05 mm
(3) 2.10 mm (4) 2.05 mm

16. The circular divisions of shown screw gauge are 50. It moves 0.5 mm on main scale in one rotation. The diameter of the ball is





(1) 2.25 mm (2) 2.20 mm
(3) 1.20 mm (4) 1.25 mm

17. A student measured the length of a rod and wrote it as 3.50 cm. Which instrument did he use to measure it ?
(1) A screw gauge having 100 divisions in the circular scale and pitch as 1 mm.
(2) A screw gauge having 50 divisions in the circular scale and pitch as 1 mm.
(3) A meter scale
(4) A vernier caliper where the 10 divisions in vernier scale matches with 9 division in main scale and main scale has 10 divisions in 1 cm.

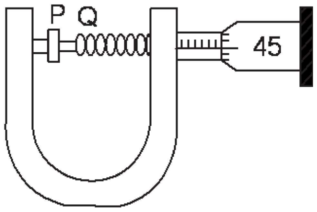
18. The pitch and the number of divisions, on the circular scale, for a given screw gauge are 0.5 mm and 100 respectively. When the screw gauge is fully tightened without any object, the zero of its circular scale lies 3 divisions below the mean line.
The readings of the main scale and the circular scale, for a thin sheet, are 5.5 mm and 48 respectively, the thickness of this sheet is :
(1) 5.755 m (2) 5.725 mm
(3) 5.740 m (4) 5.950 mm

19. The least count of the main scale of a screw gauge is 1 mm. The minimum number of divisions on its circular scale required to measure 5μm diameter of wire is :
(1) 50 (2) 100 (3) 200 (4) 500

20. Using screw gauge of pitch 0.1 cm and 50 divisions on its circular scale, the thickness of an object is measured. It should correctly be recorded as :
(1) 2.123 cm (2) 2.125 cm
(3) 2.121 cm (4) 2.124 cm

21. A screw gauge of pitch 0.5mm is used to measure the diameter of uniform wire of length 6.8cm, the main scale reading is 1.5 mm and circular scale reading is 7. The calculated curved surface area of wire to appropriate significant figures is : [Screw gauge has 50 divisions on the circular scale]
(1) 6.8 cm^2 (2) 3.4 cm^2
(3) 3.9 cm^2 (4) 2.4 cm^2

22. In an experiment to find out the diameter of wire using screw gauge, the following observation were noted :



(a) Screw moves 0.5 mm on main scale in one complete rotation

(b) Total divisions on circular scale = 50

(c) Main scale reading is 2.5 mm

(d) 45^{th} division of circular scale is in the pitch line

(e) Instrument has 0.03 mm negative error

Then the diameter of wire is :

(1) 2.92 mm (2) 2.54 mm

(3) 2.98 mm (4) 3.45 mm

ANSWER KEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	**1**	**3**	**1**	**1**	**1**	**1**	**4**	**2**	**1**	**1**	**3**	**4**	**4**	**3**	**4**
Que.	16	17	18	19	20	21	22								
Ans.	**3**	**4**	**2**	**3**	**4**	**2**	**3**								

SIMPLE PENDULUM-DISSIPATION OF ENERGY BY PLOTTING A GRAPH BETWEEN THE SQUARE OF AMPLITUDE AND TIME

Objective : Dissipation of energy by plotting a graph between square of amplitude and time for simple pendulum.

Principle :

(i) In undamped oscillation, when a simple pendulum performs SHM, the force acting at displacement x is given by

$$F = -kx$$

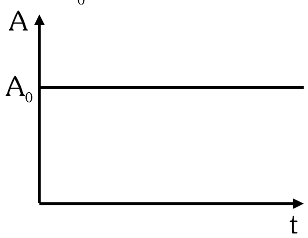
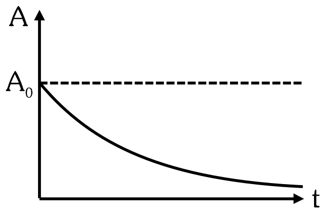
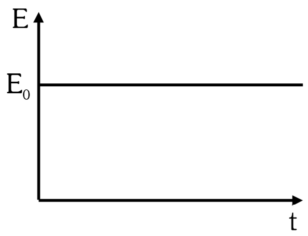
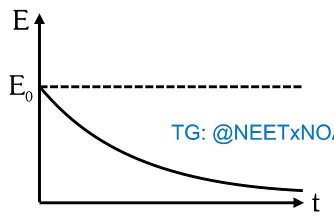
where k is force constant $= \dfrac{mg}{L}$

where m is the mass of the bob and L is its effective length.

(ii) In undamped oscillation, the amplitude and energy of simple pendulum remains constant.

(iii) In real world, when a simple pendulum oscillates, its amplitude and energy do not remain constant, rather they decrease exponentially. Such kind of oscillations are known as Damped oscillations. In all system damping forces like friction are present.

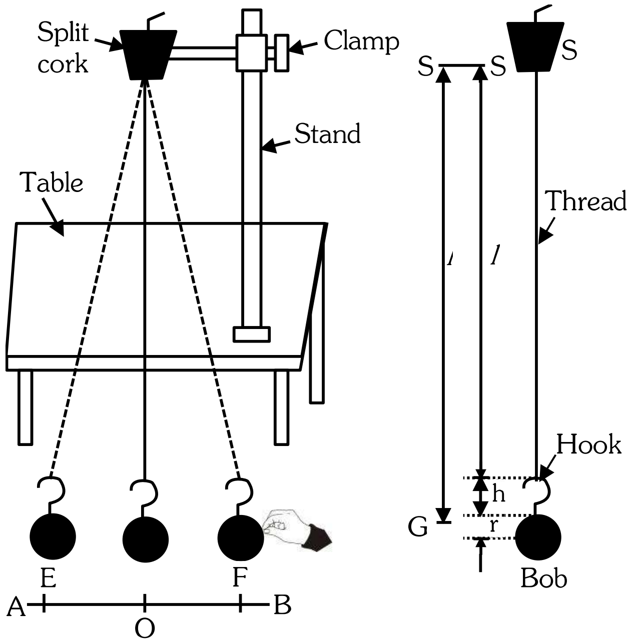
(iv) The energy of a simple pendulum is proportional to the square of amplitude of SHM. Therefore we can study the dissipation of energy of simple pendulum by plotting the graph between amplitude and time.

		Undamped oscillation	**Damped oscillation**
1.	Amplitude	$A = A_0 = \text{Constant}$  	$A = A_0e^{\frac{-bt}{2m}} = A_0e^{-\lambda t}$  **Note :** Due to damping amplitude decreases exponentially with time and becomes zero after very long time.
2.	Total energy (E)	$E_0 = \dfrac{1}{2}KA_0^2$  	$E = \dfrac{1}{2}KA^2 = \dfrac{1}{2}K\left[A_0e^{\frac{-bt}{2m}}\right]^2$ $E = \left(\dfrac{1}{2}KA_0^2\right)e^{\frac{-bt}{m}} = (E_0)e^{\frac{-bt}{m}} = E_0e^{-(2\lambda)t}$  **Note :** Due to damping, energy decreases exponentially and becomes zero after a long time.

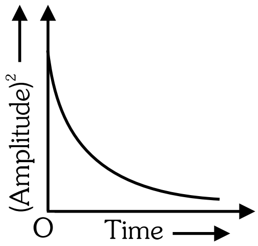
Note : You need not to remember the above exponential expression for amplitude and energy, but do remember that both amplitude and energy decreases exponentially.

Procedure:

- The experimental set for the study of dissipation of energy of an oscillating simple pendulum is as shown in figure (a) and effective length of a simple pendulum is as shown in figure (b).



- Displace the bob by some distance and observe the amplitude of bob and record time simultaneously after every alternate oscillation. Record all observation in table and the graph between amplitude square and time will be as below.



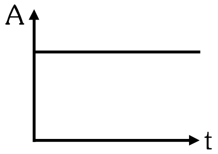
MULTIPLE CHOICE QUESTIONS

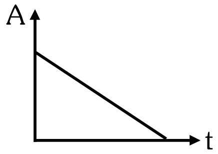
1. Which of the following changes with time when damping is considered for a SHM :-

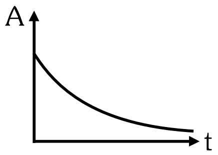
(i) Time period
(ii) Angular frequency
(iii) Amplitude
(iv) Energy

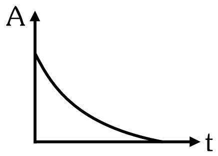
(1) (i) & (ii) (2) (iii) & (iv)
(3) All (4) (ii) & (iii)

2. Which of the following represent the correct graph for the amplitude with time for a damped SHM :-

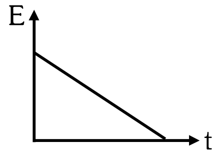
(1) 

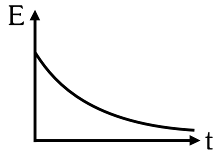
(2) 

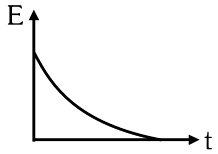
(3) 

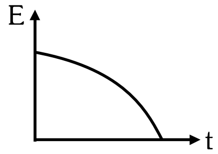
(4) 

3. Which of the following represent the graph for energy with time for a damped SHM ?

(1) 

(2) 

(3) 

(4) 

4. The amplitude of a damped times SHM becomes half in 1 minutes and $\frac{1}{x}$ times in 3 minutes. Then the value of x will be :-

(1) 16 (2) 4
(3) 8 (4) 6

5. If the amplitude of a SHM becomes $\frac{1}{27}$ times in 6 minutes and the amplitude becomes $\frac{1}{n}$ times in first 4 minutes. The value of n would be :-

(1) 4 (2) 8
(3) 6 (4) 9

6. In damped oscillation, the amplitude after 50 oscillations is 0.8 a_0 where a_0 is the initial amplitude, then amplitude after 150 oscillations is :-

(1) 0.28 a_0 (2) 0.512 a_0
(3) zero (4) a_0

ANSWER KEY

Que.	1	2	3	4	5	6
Ans.	2	3	2	3	4	2

METRE SCALE - THE MASS OF A GIVEN OBJECT BY THE PRINCIPLE OF MOMENTS

Metre Scale :- If a beam or rod is balanced under the action of different forces, then about point of balance or equilibrium position :

Sum of clockwise moments = Sum of anticlockwise moments.

or Vector sum of moments of all forces is zero about a point at which body is in equilibrium or in balanced position.

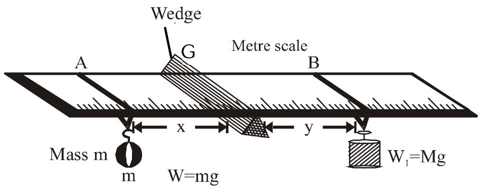
or Vector sum of clockwise and anticlockwise moments is zero about an axis of rotation chosen.

This principle is used in common balance to measure the mass of body

EXPERIMENT

Objective :- To determine the mass of a given body using a metre-scale by principle of moments.

Apparatus required :- The unknown mass m, a metre-scale, a sharp edged metal or wooden wedge, weight box, thread etc.



Principle :- On applying the principle of moments, we have

$$(mg)\ (x) = (Mg)\ (y) \Rightarrow m = M(y/x)$$

Procedure :

1. Place the sharp wedge on a wooden block so that there is sufficient space below the scale for hanging weights or masses. Now place the scale on the wedge with its graduated side, facing up.
2. Adjust the position of the scale on the wedge in such a way that its length is perpendicular to the edge of the wedge and the scale remains balaced (i.e. in the horizontal position) when no weights are suspended. This is the position of equilibrium of the scale.
3. Make two loops of cotton thread. With the help of these loops suspend the unknown weight mg on the left hand side and a known standard mass 'M' on the right hand side of the wedge as shown in figure.
4. Adjust the positions of m at A, say 10 cm from the left end of the scale in such a way that the scale gets balanced in the horizontal position.
5. When the horizontal position of the metre scale becomes stable, note the positions of masses and C.G. as A, B and G on the scale, Record AG = x and GB as y.
6. Take three more sets of observations by shifting the relative positions of mg to 15, 20 and 25 cm from the left end of the scale and adjusting corresponding positions of 'M' for balance of scale.

Calculation :

Formula $m = M\left(\frac{y}{x}\right)$

∴ Unknown mass m = mean of all calculated values

Precautions :

1. The wedge should be rigid and heavy with sharp edge.
2. Metre scale should have uniform mass distribution.
3. The threads used for loops should be light, thin and strong.

Sources of error :

1. Metre scale may have faulty calibration.
2. The threads used for loop may be thick and heavy.
3. The thread loop may not be perpendicular to metre scale.

MULTIPLE CHOICE QUESTIONS

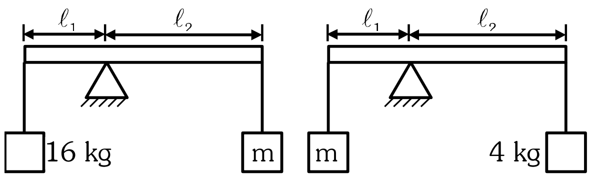
1. The centre of mass of a system of two particles divides the distance between them
(1) In inverse ratio of square of masses of particles
(2) In direct ratio of square of masses of particles
(3) In inverse ratio of masses of particles
(4) In direct ratio of masses of particles

2. A system consists of mass M and m (<< M). The centre of mass of the system is :-
(1) at the middle
(2) nearer to M
(3) nearer to m
(4) at the position of larger mass.

3. A person of mass m is standing on one end of a plank of mass M and length L and floating in water. The person moves from one end to another and stops. The displacement of the plank is –
(1) $\frac{Lm}{(m+M)}$ (2) Lm(M + m)
(3) $\frac{(M+m)}{Lm}$ (4) $\frac{LM}{(m+M)}$

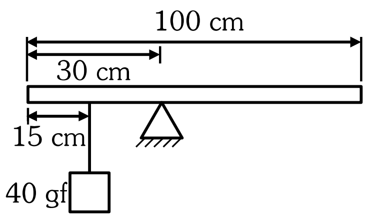
4. Two particles of mass 5 kg and 10 kg respectively are attached to the two ends of a metre scale with negligible mass.
The centre of mass of the system from the 5 kg particle is nearly at a distance of :
(1) 80 cm (2) 33 cm
(3) 50 cm (4) 67 cm

5. In an experiment with a metre scale an unknown mass m is balanced by two known masses of 16 kg and 4 kg as shown in figure. Find m.

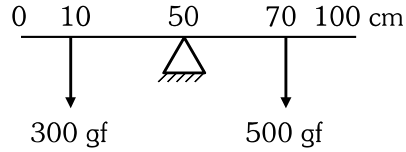


(1) 10 kg (2) 6 kg
(3) 8 kg (4) 12 kg

6. A uniform metre scale is in equilibrium position calculate the mass of the scale.
(1) 20 g (2) 30 g
(4) 40 g (4) 10 g

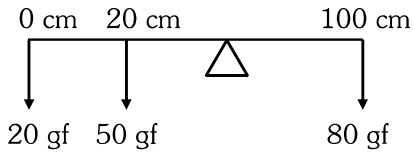


7. Figure shows a uniform meter scale weighing 200 gf, pivoted at its centre. Two weight 300 gf and 500 gf are suspended from the ruler as shown in the diagram. The distance from mid point where a 200 gf should be suspended to balance the meter scale is :



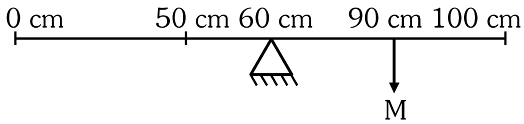
(1) 10 cm (2) 30 cm
(3) 5 cm (4) 20 cm

8. A beam of length 100 cm under the effect of three forces as shown in figure. What is the distance of wedge on beam from 80 gf so that the beam remains horizontal in equilibrium?



(1) 30 cm (2) 35 cm
(3) 40 cm (4) 50 cm

9. A uniform metre scale is kept in equilibrium it is supported at 60 cm mark and mass M is suspended at 90 cm mark shown in the figure. What is the relation between the weight of the scale (W) and the weight of mass (M).



(1) W > M (2) W < M
(3) W = M (4) Data in sufficient

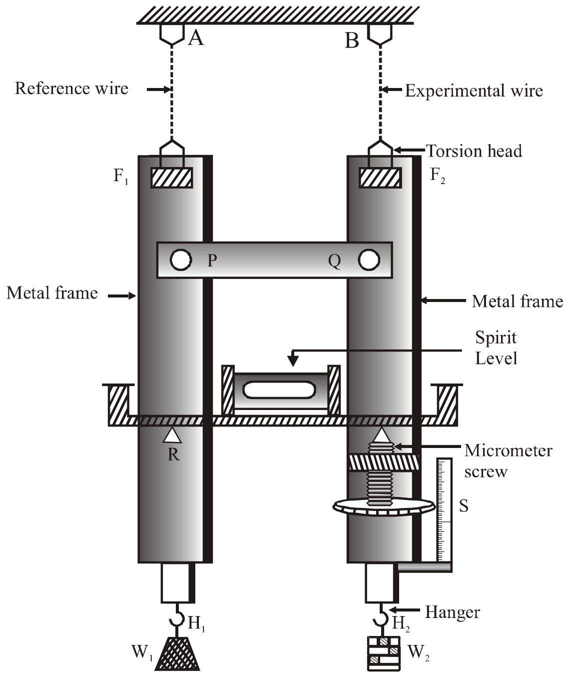
10. A uniform metre scale is balanced at 60 cm mark, when weight of 5 gf and 40 gf are suspended at 10 cm and 80 cm mark respectively. Calculate the weight of the metre scale.
(1) 65 gf (2) 60 gf (3) 75 gf (4) 55 gf

ANSWER KEY

Que.	1	2	3	4	5	6	7	8	9	10
Ans.	3	2	1	4	3	2	1	3	1	4

YOUNG'S MODULUS OF ELASTICITY OF THE MATERIAL OF A METALLIC WIRE

Introduction of Searle's Apparatus :



Searle's apparatus for determination of Y

Two wire A and B are attached to two frames F_1 and F_2. Wire A is reference wire while B is experimental wire. Each frame has hook (H_1 and H_2) to suspend slotted weights W_1 and W_2 to stretch the experimental wire. Frames are hinged by bar PQ so that only vertical relative motion is permissible. A spirit level is connected such that R is a rigid tip while C is tip of screw of spherometer with least count 0.01 mm.If experimental wire extends spherometer slides down along with frame F_2 and spirit level bubble is displaced. To bring back the bubble in original position screw is moved up or down.

EXPERIMENT

Objective: Determine Young's modulus of elasticity of the material of a given wire by using Searle's apparatus.

Apparatus required : - Searle's apparatus, a metre scale, a screw gauge, slotted weights, hanger etc.

Principle :- If a wire of length L and cross-section A is stretched by an amount ℓ by a force F acting along its length, then

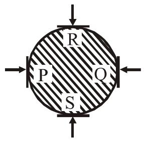
Stress = $\dfrac{F}{A}$ and strain = $\dfrac{\ell}{L}$ $\quad\therefore\quad$ Young's modulus $Y = \dfrac{F}{A} \times \dfrac{L}{\ell}$

where F = Mg and A = $\pi r^2 \Rightarrow \boxed{Y = \dfrac{MgL}{\pi r^2 \ell}}$

Procedure :

1. Attach weights to the hooks of both the frames so that the wires A and B become free from kinks and stretched. Then prepare it for the experiment by loading and unloading one kilogram weight on the hanger of the experimental wire B to remove its fatigue and attached only a constant weight W on the hook H_1 to keep the reference wire A taut.

2. Measure the length of the experimental wire from the point where it leaves the fixed support to the point where it is fixed in the frame. Find the pitch and least count of the screw gauge and determine the diameter of the wire at about ten different places and at each place in two mutually perpendicular directions. Determine the mean diameter and radius.



3. Consult the table of constants and find the breaking stress for the steel wire used. The maximum load should not exceed one-third of the breaking stress. Find the pitch and the least count of the micrometer attached to the frame and adjust it such that the bubble in the spirit level is exactly in the centre. Take the reading of the micrometer.
4. Now, increase gradually the load on the hanger of the experimental wire B in steps of 0.5 kg. Observe the reading on the micrometer at each stage, after levelling the instrument with the spirit level till the maximum permissible load is reached. In these cases the adjusting screw has to be moved upwards to bring the bubble in the centre. To avoid back lash error, all the final adjustments should be made by moving the screw in the upward direction only. If at any time the screw is raised too much, lower it below the central position and then raise it slowly to the proper position.
5. Unload the wire by removing the weights in the same order and take the reading on the micrometer screw each time. In this case the screw has to be moved downwards but again, to avoid the back lash error, move the screw in the same direction only. These readings taken for a particular load while loading the wire or unloading the wire, should agree closely.

Precautions :

1. Both the wires should be supported from same rigid support.
2. Kinks should be removed from experimental wire before starting the experiment.
3. Diameter of wire should be measured at different places and along two mutually perpendicular directions at every place.
4. Slotted weights should be added and removed gently.
5. We should wait for taking observations after adding or removing weight.
6. Load should be increased or decreased in regular steps.
7. Do not load the wire beyond one-third of the breaking stress.
8. To avoid backlash error, the screw should always be turned in the same direction.

Sources of Error :

1. Experimental wire may not have uniform cross-section through-out.
2. The slotted weights may not have standard weight.
3. The screw gauge may have friction or backlash error.

MULTIPLE CHOICE QUESTIONS

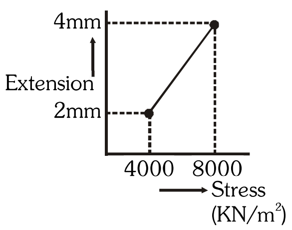
1. In the Searle's experiment following four wires are made of the same material. Which of these will have the largest extension when the same tension is applied ?
(1) length = 300cm, diameter = 3mm
(2) length = 50 cm, diameter = 0.5 mm
(3) length = 100 cm, diameter = 1mm
(4) length = 200 cm, diameter = 2mm

2. Copper of fixed volume 'V; is drawn into wire of length 'ℓ'. When this wire is subjected to a constant force 'F', the extension produced in the wire is '$\Delta\ell$'. Which of the following graphs is a straight line ?
(1) $\Delta\ell$ versus $\frac{1}{\ell}$ (2) $\Delta\ell$ versus ℓ^2
(3) $\Delta\ell$ versus $\frac{1}{\ell^2}$ (4) $\Delta\ell$ versus ℓ

3. The Young's modulus of steel is twice that of brass. Two wires of same length and of same area of cross section, one of steel and another of brass are suspended from the same roof. If we want the lower ends of the wires to be at the same level, then the weights added to the steel and brass wires must be in the ratio of :
(1) 1 : 1 (2) 1 : 2 (3) 2 : 1 (4) 4 : 1

4. In a Searle's experiment two wires are made of the same material and have the same volume. The first wire has cross-sectional area A and the second wire has cross-sectional area 3A. If the length of the first wire is increased by Δl on applying a force F, how much force is needed to stretch the second wire by the same amount ?
(1) 9F (2) 6F (3) 4F (4) F

5. In determination of Young's modulus of elasticity of wire, a force is applied and extension is recorded. Initial length of wire is '1m'. The curve between extension and stress is depicted then Young's modulus of wire will be :-



(1) $2\times10^9\,N/m^2$ (2) $1\times10^9\,N/m^2$
(3) $2\times10^{10}\,N/m^2$ (4) $1\times10^{10}\,N/m^2$

6. In a Searle's experiment for determination of Young's Modulus, when a load of 50 kg is added to a 3 meter long wire micrometer screw having pitch 1 mm, needs to be given a quarter turn in order to restore the horizontal position of spirit level. Young's modulus of the wire if its cross sectional area is 10^{-5} m^2 is
(1) $5.88\times10^{11} N/m^2$
(2) $1.5\times10^{11}\,N/m^2$
(3) $3\times10^{11}\,N/m^2$
(4) None

7. In Searle's apparatus, when experimental wire is loaded and unloaded, the air bubble in spirit level gets shifted.
(1) towards reference wire while loading & towards experimental wire while unloading
(2) towards experimental wire while loading & towards reference wire while unloading
(3) towards experimental wire, both the times, during loading & unloading
(4) towards reference wire, both the times during loading & unloading

8. A student performs an experiment to determine the Young's modulus of a wire, exactly 2 m long, by Searle's method. In a particular reading, the student measures the extension in the length of the wire to be 0.8 mm with an uncertainty of ±0.05 mm at a load of exactly 1.0 kg. The student also measures the diameter of the wire to be 0.4 mm with an uncertainty of ±0.01 mm. Take g = 9.8 m/s^2 (exact). The Young's modulus obtained from the reading is
(1) $(2.0 \pm 0.3)\times10^{11}\,N/m^2$
(2) $(2.0 \pm 0.2)\times10^{11}\,N/m^2$
(3) $(2.0 \pm 0.1)\times10^{11}\,N/m^2$
(4) $(2.0 \pm 0.05)\times10^{11}\,N/m^2$

9. In the determination of Young's modulus $\left(Y = \frac{4MLg}{\pi \ell d^2}\right)$ by using Searle's method, a wire of length L = 2m and diameter d = 0.5 mm is used. For a load M = 2.5 kg, an extension l = 0.25 mm in the length of the wire is observed. Quantities d and l are measured using a screw gauge and a micrometer, respectively. They have the same pitch of 0.5 mm. The number of divisions on their circular scale is 100. The contributions to the maximum probable error of the 'Y' measurement

(1) due to the errors in the measurements of d and l are the same.

(2) due to the error in the measurement of d is twice that due to the error in the measurement of l.

(3) due to the error in the measurement of l is twice that due to the error in the measurement of d.

(4) due to the error in the measurement of d is four times that due to the error in the measurement of l.

10. In a Searle's experiment, the diameter of the wire as measured by a screw gauge of least count 0.001 cm is 0.050 cm. The length, measured by a scale of least count 0.1 cm, is 100 cm. When a weight of 50 N is suspended from the wire, the extension is measured to be 0.125 cm by a micrometer of least count 0.001 cm. Find the maximum error in the measurement of Young's modulus of the material of the wire from these data.

(1) 48.90 Y (2) 4.580 Y
(3) 0.489 Y (4) 0.049 Y

11. In order to determine the Young's Modulus of a wire of radius 0.2 cm (measured using a scale of least count = 0.001 cm) and length 1m (measured using a scale of least count = 1 mm), a weight of mass 1kg (measured using a scale of least count = 1g) was hanged to get the elongation of 0.5 cm (measured using a scale of least count 0.001 cm). What will be the fractional error in the value of Young's Modulus determined by this experiment ?

(1) 0.14% (2) 0.9%
(3) 9% (4) 1.4%

12. A student determined Young's Modulus of elasticity using the formula $Y = \frac{MgL^3}{4bd^3\delta}$. The value of g is taken to be 9.8 m/s^2, without any significant error, his observation are as following.

Physical Quantity	Least count of the Equipment used for measurement	Observed value
Mass (M)	1 g	2 kg
Length of bar (L)	1 mm	1 m
Breadth of bar (b)	0.1 mm	4 cm
Thickness of bar (d)	0.01 mm	0.4 cm
Depression (δ)	0.01 mm	5 mm

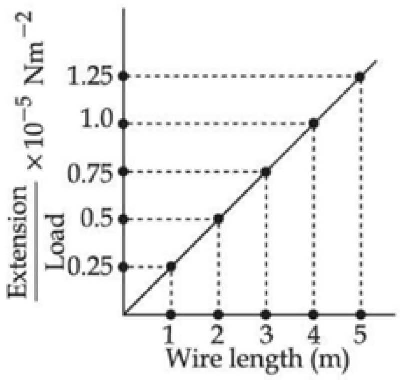
Then the fractional error in the measurement of Y is :

(1) 0.0083 (2) 0.0155
(3) 0.155 (4) 0.083

13. In an experiment of determine the Young's modulus of wire of a length exactly 1m, the extension in the length of the wire is measured as 0.4mm with an uncertainty of ± 0.02 mm when a load of 1kg is applied. The diameter of the wire is measured as 0.4mm with an uncertainty of ± 0.01 mm. The error in the measurement of Young's modulus (ΔY) is found to be $x \times 10^{10}$ Nm^{-2}. The approximate value of x is _____. [Take : g = 10 m/s^2]

(1) 1 (2) 2 (3) 3 (4) 4

14. In an experiment to determine the Young's modulus, steel wires of five different lengths (1, 2, 3, 4 and 5 m) but of same cross section (2 mm^2) were taken and curves between extension and load were obtained. The slope (extension/load) of the curves were plotted with the wire length and the following graph is obtained. If the Young's modulus of given steel wires is x × 10^{11} Nm^{-2}, then the value of x is ____ .



(1) 1 (2) 2 (3) 3 (4) 4

15. The maximum load a test wire in Searle's experiment can withstand without breaking, when its length is reduced to half of its original length, will

(1) be double. (2) be half.

(3) be four times. (4) remain same.

16. Overall changes in volume and radii of a uniform cylindrical steel wire are 0.2% and 0.002% respectively when subjected to some suitable force. Longitudinal tensile stress acting on the wire is :- ($Y = 2.0 \times 10^{11}$ Nm^{-2})

(1) 3.2×10^9 Nm^{-2}

(2) 3.2×10^7 Nm^{-2}

(3) 3.6×10^9 Nm^{-2}

(4) 3.9×10^8 Nm^{-2}

17. The Young's modulus of a wire of length L and radius r is Y newton per square metre. If the length is reduced to L/2 and radius to r/2, its Young's modulus will be :-

(1) $\frac{Y}{2}$ (2) Y (3) 2 Y (4) 4Y

18. When a mass of 5kg is hung on a wire then extension of 30 cm take place then work done will be :- ($g = 10$ m/s^2)

(1) 7.5 J (2) 15 J

(3) 0.5 J (4) 1.5 J

19. In Searle's experiment reference wire of cross-sectional area 3×10^{-6} m^2 can withstand a maximum strain of 10^{-3}. Young's modulus of steel is 2×10^{11} N/m^2. The maximum mass the wire can hold is:- (Take $g = 10$ m/s^2)

(1) 40 kg (2) 60 kg

(3) 80 kg (4) 100 kg

20. The Young's modulus of the material of a wire is equal to the :-

(1) stress required to increase its length four times

(2) stress required to produce unit strain

(3) strain produced in it

(4) half the strain produced in it

21. A steel wire of diameter 0.5 mm and Young's modulus 2×10^{11} N m^{-2} carries a load of mass M. The length of the wire with the load is 1.0 m. A vernier scale with 10 divisions is attached to the end of this wire. Next to the steel wire is a reference wire to which a main scale, of least count 1.0 mm, is attached. The 10 divisions of the vernier scale correspond to 9 divisions of the main scale. Initially, the zero of vernier scale coincides with the zero of main scale. If the load on the steel wire is increased by 1.2kg, the vernier scale division which coincides with a main scale division is.......

[Take $g = 10$ ms^{-2} and $\pi = 3.2$]

(1) 1 (2) 2 (3) 3 (4) 4

22. The temperature of a wire is doubled. The Young's modulus of elasticity

(1) will also double.

(2) will become four times.

(3) will remain same.

(4) will decrease.

23. A vertical experimental wire in Searle's experiment steel wire of diameter 25 cm and length 2.5 m supports a weight of 8000 kg. The change in length produced is :

(Given $Y = 2 \times 10^{11}$ Pa)

(1) 0.21 mm (2) 0.021 mm

(3) 0.021 cm (4) 0.021 cm

ANSWER KEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	2	2	3	1	1	1	1	2	1	4	4	2	2	2	4
Que.	16	17	18	19	20	21	22	23							
Ans.	4	2	1	2	2	3	4	2							

SURFACE TENSION OF WATER BY CAPILLARY RISE AND EFFECT OF DETERGENTS

Introduction

Surface tension is basically a property of liquid surface. The liquid surface behaves like a stretched elastic membrane which has a natural tendency to contract and tends to have a minimum surface area. This property of liquid is called *surface tension*.

Intermolecular forces

(a) **Cohesive force** : The force acting between the molecules of one type of molecules of same substance is called cohesive force.

(b) **Adhesive force :** The force acting between different types of molecules or molecules of different substance is called adhesive force.

- Intermolecular forces are different from the gravitational forces and do not obey the inverse–square law
- The distance upto which these forces effective, is called molecular range. This distance is nearly 10^{-9} m. Within this limit, force increases very rapidly as the distance decreases.
- Molecular range depends on the nature of the substance

Dependency of Surface Tension

- **On Cohesive Force :** Those factors which increase the cohesive force between molecules increase the surface tension and those which decrease the cohesive force between molecules decrease the surface tension.
- **On Impurities :** If the impurity is completely soluble then on mixing it in the liquid, its surface tension increases. e.g., on dissolving ionic salts in small quantities in a liquid, its surface tension increases. If the impurity is partially soluble in a liquid then its surface tension decreases because adhesive force between insoluble impurity molecules and liquid molecules decreases cohesive force effectively, e.g.

  (a) On mixing detergent in water its surface tension decreases.

  (b) Surface tension of water is more than (alcohol + water) mixture.
- **On Temperature :** On increasing temperature surface tension decreases. At critical temperature and boiling point it becomes zero. **Note :** Surface tension of water is maximum at 4°C
- **On Contamination :** The dust particles or lubricating materials on the liquid surface decreases its surface tension.

Definition of surface tension

The force acting per unit length of an imaginary line drawn on the free liquid surface at right angles to the line and in the plane of liquid surface, is defined as surface tension.

ANGLE OF CONTACT (θ_C)

The angle enclosed between the tangent plane at the liquid surface and the tangent plane at the solid surface at the point of contact inside the liquid is defined as the *angle of contact*.

The angle of contact depends the nature of the solid and liquid in contact.

- **Angle of contact** $\theta < 90° \Rightarrow$ meniscus is concave shape, Liquid rise up & wet the solid surface.
  Angle of contact $\theta > 90° \Rightarrow$ meniscus is convex shape, Liquid falls & θ do not wet solid surface.
  Angle of contact $\theta = 90° \Rightarrow$ meniscus is plane shape, Liquid neither rise nor falls

- **Effect of Temperature on angle of contact**

  On increasing temperature surface tension decreases, thus $\cos\theta_c$ increases $\left[\because \cos\theta_c \propto \frac{1}{T}\right]$ and θ_c decrease.

  So on increasing temperature, θ_c decreases.

- **Effect of Impurities on angle of contact**

  (a) Solute impurities increase surface tension, so $\cos\theta_c$ decreases and angle of contact θ_c increases.

  (b) Partially solute impurities decrease surface tension, so angle of contact θ_c decreases.

- **Effect of Water Proofing Agent**

  Angle of contact increases due to water proofing agent. It gets converted acute to obtuse angle.

Capillary Tube and Capillarity

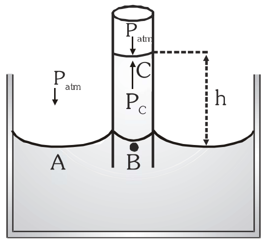
The property by virtue of which a liquid rises or gets depressed in a capillary tube is known as ***capillarity***.

Rise or fall of liquid in tubes of narrow bore (capillary tube) is called ***capillary action***.

Calculation of Capillary Rise

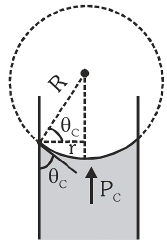
(i) Pressure Balance Method :

When a capillary tube is first dipped in a liquid as shown in the figure, the liquid climbs up the walls curving the surface. Let the radius of the meniscus be R and the radius of the capillary tube be r. Angle of contact is θ_C, surface tension is T, density of liquid is ρ and the liquid rises to a height h.



R= Radius of the meniscus

Enlarged view



$R = \frac{r}{\cos\theta}$

Now let us consider two points A and B at the same horizontal level as shown. By Pascal's law

$$P_A = P_B \quad \Rightarrow \quad P_A = P_C + \rho gh$$

Now, point C is on the curved meniscus which has P_{atm} and P_C as the pressures on its concave and convex sides respectively.

$$\therefore\ P_{atm} = (P_{atm} - \frac{2T}{R}) + h\rho g \ \Rightarrow\ h = \frac{2T}{R\rho g} = \frac{2T\cos\theta_C}{r\rho g}$$

(ii) Force Balance Method :-

The liquid continues to rise in the capillary tube until the weight of the liquid column becomes equal to force due to surface tension.

In equilibrium : force due to S.T = weight of rise liquid

$$(2\pi r)T\cos\theta_C = mg$$

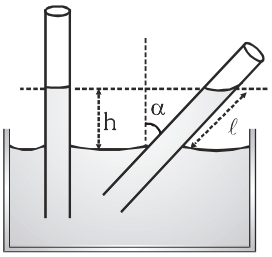
$$h = \frac{2T\cos\theta_C}{r\rho g}$$

- **Zurin's Law** :

  The height of rise of liquid in a capillary tube is inversely proportional to the radius of the capillary tube, if T, θ, ρ and g are constant $h \propto \frac{1}{r}$ or rh = constant. It implies that liquid will rise more in capillary tube of less radius and vice versa.

Important key points :

- For pure water and clean glass capillary $\theta_c \approx 0° \Rightarrow$ Radius of meniscus = radius of capillary
- Rise of liquid in a capillary tube does not obey the law of conservation of mechanical energy.
- Inside a satellite, water will rise upto the top level but will not overflow. Radius of curvature (R') increases in such a way that final height h' is reduced and given by $h' = \frac{hR}{R'}$. (It is in accordance with Zurin's law).
- If a capillary tube is dipped into a liquid and tilted at an angle α from vertical then the vertical height of the liquid column remains same whereas the length of liquid column in the capillary tube increases.



$$h = \ell\cos\alpha \Rightarrow \ell = \frac{h}{\cos\alpha}$$

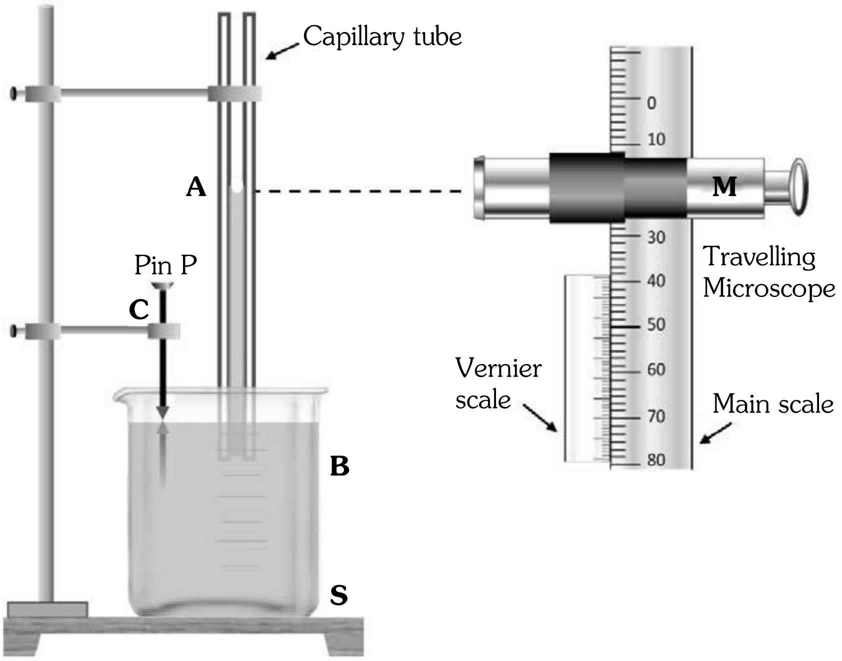
- The height 'h' is measured from the lowest point of the meniscus. However, there exists some liquid above this line also. If correction is applied then the formula will be $T = \dfrac{r\rho g\left[h + \frac{1}{3}r\right]}{2\cos\theta}$

EXPERIMENT

Objective: To determine the surface tension of water by capillary rise method.

Apparatus and material required : A glass/plastic capillary tube, travelling microscope, beaker, fine motional adjustable stand, cork with pin, clean tap water, dilute nitric acid solution, dilute caustic soda solution, clamp stand, plumb line and a thermometer etc.

Principle : When a liquid rises in a capillary tube, whose one end is placed in the liquid, the weight of the column of liquid of density ρ below the meniscus, is supported by the upward force of surface tension acting around the circumference of point of contact. Therefore,



To determine the surface tension of liquid by capillary rise method

$$2\pi rT = \pi r^2 h\rho g \qquad \text{(approx for water)}$$

$$\text{or} \quad T = \frac{h\rho gr}{2}$$

where T = surface tension of the liquid

h = height of the liquid column and

r = inner radius of the capillary tube

Procedure :

(1) Experiment should be performed in a well-lit place with good ambient visibility

(2) Clean the capillary tube and beaker successively in caustic soda and nitric acid and finally rinse thoroughly with water.

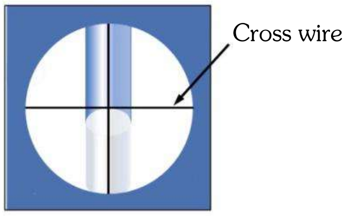
(3) A Beaker is placed on a stand S which is adjustable. Fill the beaker with the tap water, free from dirt or grease such that the free surface of water stands a little below the edge of the beaker. Measure the temperature of water

(4) Clamp the capillary tube near its upper end shown. Adjust it to be vertical with the help of plumb line. Fill the beaker near to the brim with water. Adjust the position of the adjustable stand, in such a way that the lower end of the capillary tube is well within water in beaker as shown in figure

(5) Mount a fine pin P through the cork C on another clamp, parallel to the capillary tube, such that its tip just above the water surface, as shown in figure. Slowly lower the pin, till its tip just touches the water surface. This can be done by coinciding the tip of the pin with the water surface.

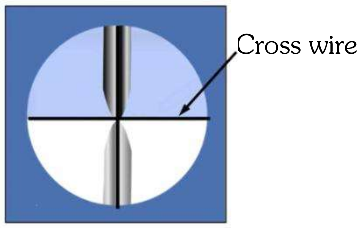
Measurement of capillary rise:

(6) Calculate and record least count of the travelling microscope M. Raise the microscope to a suitable height, keep its axis horizontal and view the water meniscus in the tube, through the microscope. Make adjustment so that the horizontal cross wire just touches the lowest point of the concave meniscus M which looks inverted as shown in figure. Note this reading of the travelling microscope.



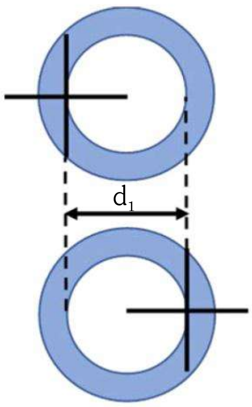
Magnified and inverted view of meniscus in the capillary

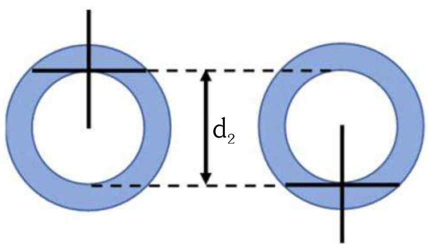
(7) Now lower the microscope till the horizontal cross wire is midway between lower pointed end of the needle and its image in water as shown in figure. (This gives the position of the free surface of the water). Record this reading of the microscope too. The difference between these two readings gives the height of the water column.



Magnified view of needle just touching the water surface

(8) To find the radius r of a capillary tube, put an ink mark at the point where the meniscus stood and cut capillary at this point carefully with sharp edge of a blade. Never break the tube by bending as it would cause an unveven fracture. To get an even and clear fracture, scratch the tube at ink mark by a sharp blade and apply tension along the length of the tube.





Position of cross wire of T.M, for the measurement of internal diameter of capillary in two mutually perpendicular directions

Fix the cut tube horizontally on the clamp stand. Focus the microscope on the transverse cross-section of the tube end and measure its internal diameter in two mutually perpendicular directions (horizontal and vertical) by adjusting the travelling microscope and noting the readings as shown in figure.

Observations :

Determination of 'h'

Least Count of the travelling microscope = mm

Measurement of diameter of the capillary tube

Mean radius of capillary tube r = cm; Temperature of water θ =

Calculation:

Substitute the value of 'h' and 'r' and 'ρ g' in the formula for T to calculate the value of surface tension at particular temperature

Result:

Surface tension of water at _____°C = _____ $\pm$ ____Nm^{-1}

Precautions:

1. Capillary tube should be free of any contamination. To clean the capillary tube, it must rinsed first in a solution of caustic soda then with dilute nitric acid and finally cleaned with water thoroughly.
2. The capillary tube must set vertical
3. Ensure that capillary tube is sufficiently wet, raise and lower water level in container by lifting or lowering the beaker. It should have no effect on the height of the liquid in capilary tube.
4. Microscope should be moved in lower direction only so as to avoid backlash error
5. Height of the meniscus should be measured from the lowest point of the concave meniscus
6. Internal diameter of the capillary, should be measured in two mutually perpendicular directions
7. Temperature of water must be recorded in the beginning and also at the end

Sources of error:

1. Inserting dry capillary tube can cause gross error as liquid level may not fall back when the level in container is lowered
2. Capillary tube may not have uniform bore
3. Temperature of water may not be constant during the experiment
4. Surface tension changes with impurities and temperature
5. Microscope may have back lash error so it has to be moved in one direction only

Discussion:

1. In fine capillary tube, meniscus may by considered as nearly hemispherical and the weight of the liquid above the lowest point of the meniscus is $\left(\frac{1}{3}\right)\pi r^3 \rho g$.

   Taking this into account, the more precise formula for surface tension can be given as

$$T = \frac{1}{2}\rho g r\left(h + \frac{r}{3}\right)$$

2. In using dry capillary tube, the water level in capillary may not fall down when the container is lowered. To prevent this, before performing the experiment capillary tube must be made wet well or rinsed from inside thoroughly. Alternatively, same can be achieved by raising and lowering the beaker

Further activities :

1. Experiment can be performed at different temperatures and effect of temperature on surface tension can be studied
2. Experiment can be performed after adding soluble (like adding NaCl or sugar) and insoluble impurities and effect of change in impurity concentration on surface tension can be studied.
3. Study the effect of inclination of capillary tube on height of liquid rise in the capillary tube
4. Effect of using the capillary of length smaller than the normal liquid level rise and check whether the liquid overflows out or not
5. Effect of change in effective diameter (hence radius) of the capillary, on the height of liquid rise, for same liquid
6. Experiment can be performed by using low concentration of detergent mixed with water and compare the height of liquid rise as compare to normal pure water.

Interesting facts about surface tension:

1. Water strider insects can travel on the surface of water which acts as stretched membrane.
2. Sparingly soluble impurities in water may decrease the surface tension (ex. Phenol, Dettol etc), on the other hand completely soluble impurities may increase the surface tension.
3. Detergents / soaps increases the cleaning effect of water by decreasing the cohesive forces among water molecules.
4. Soap bubbles balance surface tension forces against internal pneumatic excess pressure.
5. Small irregular camphor pieces run/dance on the surface of water as the camphor decreases the surface tension of water near its ends, unevenly, thus creating imbalance of intermolecular forces of attraction and causes differential pressure. Thus, surface tension at different ends of camphor are different and this unbalance force created by uneven surface tension sets the pieces of camphor to run or dance.
6. Hairs of fine brush gets stick close together, when taken out of water or liquid due to surface tension which tries to minimize the liquid surface area.

MULTIPLE CHOICE QUESTIONS

1. The spherical shape of rain-drop is due to :-
(1) Density of the liquid
(2) Surface tension
(3) Atmospheric pressure
(4) Gravity

2. The property utilized in the manufacture of lead shots is :-
(1) Specific weight of liquid lead
(2) Specific gravity of liquid lead
(3) Compressibility of liquid lead
(4) Surface tension of liquid lead

3. Adding detergents to water helps in removing dirty greasy stains. This is because :-
(a) It increases the oil-water surface tension
(b) It decreases the oil-water surface tension
(c) It increases the viscosity of the solution
(d) Dirt is held suspended surrounded by detergent molecules
(1) (b) and (d) (2) (a) only
(3) (c) and (d) (4) (d) only

4. Spiders and insects move and run on the surface of water without sinking because :-
(1) Elastic membrane is formed on water due to property of surface tension
(2) Spiders and insects are lighter
(3) Spiders and insects swim on water
(4) Spiders and insects experience up-thrust

5. Shape of meniscus for a liquid of zero angle of contact is :-
(1) plane (2) parabolic
(3) hemi-spherical (4) cylindrical

6. A liquid does not wet the sides of a solid, if the angle of contact is :-
(1) Zero
(2) Obtuse angle (more than 90°)
(3) Acute angle (less than 90°)
(4) 45°

7. If a wax coated capillary tube is dipped in water, then water in it will :-
(1) rise up
(2) depress
(3) sometime rise and sometime fall
(4) rise up and come out as a fountain

8. Two capillaries of same material but of different radii are dipped in a liquid. In one of the capillary the liquid rises to a height of 22 cm and in other to 66 cm. The ratio of their radii is :-
(1) 9 : 1 (2) 6 : 1 (3) 3 : 1 (4) 4 : 1

9. If a capillary of radius r is dipped in water, the height of water that rises in it is h and its mass is M. If the radius of the capillary is halved the mass of water that rises in the capillary will be :-
(1) 4M (2) 2M (3) M (4) $\frac{M}{2}$

10. When a capillary tube of glass is dipped into a tub containing mercury then the mercury level in the capillary goes down because the pressure just below the meniscus is :-
(1) zero
(2) equal to atmospheric pressure
(3) less than atmospheric pressure
(4) more than the atmospheric pressure

11. In a surface tension experiment with a capillary tube water rises up to 10 cm. If the same experiment is repeated on an artificial satellite which is revolving round the earth, water will rise in the capillary tube up to a height of :-
(1) 0.1 m
(2) 0.98 m
(3) 9.8 m
(4) full length of capillary tube

12. Water rises to a height h in a capillary at the surface of earth. On the surface of the moon the height of water column in the the same capillary will be :-
(1) 6h (2) 1/6 h (3) h (4) Zero

13. Two capillary tubes of same diameter are put vertically one each in two liquids whose relative densities are 1.6 and 0.6 and surface tensions are 240 dyne/cm and 300 dyne/cm respectively. Ratio of heights of liquids in the two tubes h_1/h_2 is :-
(1) $\frac{10}{9}$ (2) $\frac{3}{10}$ (3) $\frac{10}{3}$ (4) $\frac{9}{10}$

14. Radius of a capillary is 0.2 cm. A liquid of weight 6.2 N may remain in equilibrium in the capillary. Then the surface tension of liquid will be ($\theta_C = 0°$):-
(1) 5×10^{-3} N/m (2) 5×10^{-2} N/m
(3) 50 N/m (4) 500 N/m

15. Water rise in a capillary upto an extension height such that upward force of surface tension balances the force of 75×10^{-4} N due to weight of water. If surface tension of water is 6×10^{-2} N/m. The internal circumference of the capillary must be :-

(1) 12.5×10^{-2} m (2) 6.5×10^{-2} m
(3) 0.5×10^{-2} m (4) 1.25×10^{-2} m

16. Internal radius of a capillary tube is $\frac{1}{14}$ cm and surface tension of water is 70 dyne/cm, if angle of contact is zero, then water will rise up in the tube up to height (g = 980 cm/s^2) :-

(1) 4 cm (2) 2 cm (1) 14 cm (2) 18 cm

17. Water rises in a capillary upto a height of 4 cm. If it is tilted to 30° from the vertical, then the length of water column in it will be :-

(1) $\frac{8}{\sqrt{3}}$ cm (2) $8\sqrt{3}$ cm (3) 4 cm (4) 2 cm

18. The wettability of a surface by a liquid depends primarily on :-

(1) angle of contact between the surface and the liquid
(2) viscosity
(3) surface tension
(4) density

19. Water rises to height 'h' in capillary tube. If the length of capillary tube above the surface of water is made less than 'h', then -

(1) water does not rise at all.
(2) water rises upto the tip of capillary tube and then starts overflowing like a fountain.
(3) water rises upto the top of capillary tube and stays there without overflowing.
(4) water rises upto a point a little below the top and stays there.

20. Three liquids of densities ρ_1, ρ_2 and ρ_3 (with $\rho_1 > \rho_2 > \rho_3$), having the same value of surface tension T, rise to the same height in three identical capillaries. The angles of contact θ_1, θ_2 and θ_3 obey:-

(1) $\frac{\pi}{2} < \theta_1 < \theta_2 < \theta_3 < \pi$

(2) $\pi > \theta_1 > \theta_2 > \theta_3 > \frac{\pi}{2}$

(3) $\frac{\pi}{2} > \theta_1 > \theta_2 > \theta_3 \geq 0$

(4) $0 \leq \theta_1 < \theta_2 < \theta_3 < \frac{\pi}{2}$

21. While performing experiment to measure surface tension of water using capillary rise method, the necessary precautions to be taken is:

(a) both capillary tube, and water should be free from contamination
(b) capillary tube should be clean while water may contain some dirt or grease
(c) temperature of water should be observed while performing experiment
(d) internal diameter of capillary should be measured in two mutually perpendicular direction

(1) (a), (c) (2) (b), (c)
(3) (a), (c) & (d) (4) (c), (d)

22. While measuring the surface tension of water, by capillary rise method, which of the following precaution is/are necessary.

(a) Capillary tube and water must be clean and free from contamination/ grease
(b) Capillary tube should be set vertical & The temperature of the water should be noted
(c) Travelling microscope should be moved in lower direction only avoid back lash error
(d) Internal diameter of capillary tube should be measured in two mutually perpendicular directions

(1) (b) & (c) (2) (b)
(3) (d) & (e) (4) (a), (b), (c) & (d)

23. Choose the incorrect statement among the following

(1) capillary action is due to both cohesion and adhesion
(2) falling raindrop becomes a spherical due to cohesion and surface tension
(3) surface tension is due to cohesion between atoms at the free surface
(4) mixing soap solution with water, increases its surface tension

24. If an end of a capillary tube is dipped into a liquid then

(1) liquid level will rise in the tube
(2) liquid level will depress in the tube
(3) liquid level will remain constant as of surrounding liquid
(4) any of the above may be possible

25. If the angle of contact of a drop of liquid is acute then

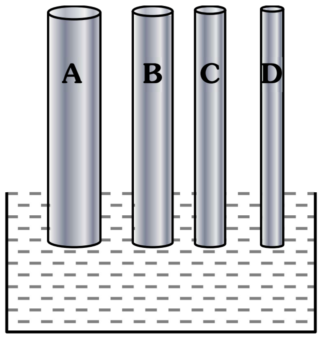
(1) cohesion, is equal to adhesion

(2) cohesion is more than adhesion

(3) adhesion is more than cohesion

(4) both adhesion and cohesion have no connection with the angle of contact

26. Four Capillaries of different bores are dipped in same liquid contained in Beaker as shown. The increasing order of the respective height attained by the liquid in the capillaries will be:



(1) A B C D (2) D C B A

(3) A D C B (4) C B D A

27. The phenomena of rise or fall of liquid level in a capillary tube is called as capillarity. In non-wetting liquids like mercury the correct relation between cohesion of mercury and adhesion between mercury and capillary tube is:

(1) cohesion is lesser than adhesion

(2) cohesion is equal to adhesion

(3) no relation between cohesion and adhesion

(4) cohesion is greater than adhesion

28. Why does an ink filled fountain pen leak at high-altitude?

(1) Atmospheric pressure increases,

(2) atmospheric pressure decreases,

(3) temperature decreases,

(4) height increases

29. Choose the wrong statement from the following

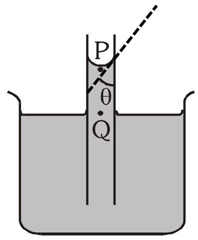
(1) small droplets of a liquid are spherical due to the surface tension

(2) oil rises through the wick due to capillarity

(3) in drinking liquids through a straw, we use of phenomenon of capillarity.

(4) None of these

30. Liquid reaches an equilibrium as shown, in a capillary tube of internal radius r. If the surface tension of the liquid is T, the angle of contact θ and density of liquid ρ, then the pressure difference between P and Q is :-



(1) $\left(\frac{2T}{r}\right)\cos\theta$ (2) $\frac{T}{r\cos\theta}$

(3) $\frac{2T}{r\cos\theta}$ (4) $\left(\frac{4T}{r}\right)\cos\theta$

31. The following observations were taken for determining surface tension T of water by capillary method :

Diameter of capillary, $D = 1.25 \times 10^{-2}$ m

rise of water, $h = 1.45 \times 10^{-2}$ m

Using $g = 9.80$ m/s^2 and the simplified relation $T = \frac{rhg}{2} \times 10^3$ N/m, the possible error in surface tension is closest to :

(1) 2.4% (2) 10% (3) 0.15% (4) 1.5%

32. Water rises to a height of 10 cm in a glass capillary tube. If the area of cross-section of the tube is reduced to one-fourth of its former value then find height of water rises in the tube.

(1) 20 cm (2) 5 cm (3) 2.5 cm (4) 7 cm

33. Liquid rises to a height of 2 cm in a capillary tube. The angle of contact between the solid and the liquid is zero. The tube is depressed more now so that the top of the capillary is only 1 cm above the liquid then the apparent angle of contact between the solid and the liquid is

(1) 0° (2) 30° (3) 60° (4) 90°

34. ***Assertion :-*** Soap solution should have small angle of contact.

Reason :- If angle of contact is small therefore Soap solution rinse the clothes dust in less time.

(1) Both (A) and (R) are true and (R) is the correct explanation of (A).
(2) Both (A) and (R) are true and (R) is NOT the correct explanation of (A).
(3) (A) is true but (R) is false.
(4) (A) is false but (R) is true.

35. ***Assertion :-*** Surface tension of a liquid is independent of the area of the surface.

Reason :- Surface tension produced due to cohesive force.

(1) Both (A) and (R) are true and (R) is the correct explanation of (A).
(2) Both (A) and (R) are true and (R) is NOT the correct explanation of (A).
(3) (A) is true but (R) is false.
(4) (A) is false but (R) is true.

36. ***Assertion :*** The angle of contact of a liquid decreases with increase in temperature.

Reason : With increase in temperature, the surface tension of liquid increases.

(1) Both (A) and (R) are true and (R) is the correct explanation of (A).
(2) Both (A) and (R) are true and (R) is NOT the correct explanation of (A).
(3) (A) is true but (R) is false.
(4) (A) is false but (R) is true.

37. Match the following with suitable options given in list II :

List-I		List-II	
I	Excess pressure	A	Independent of temperature
II	Surface energy in formation of drop	B	Varies directly with $(\text{radius})^2$
III	Capillary rise	C	In general decrease with increase in temperature
IV	Angle of contact TG: @NEETxNOAH	D	Varies inversely with $(\text{Area})^{1/2}$
		E	Varies inversely with $(\text{Volume})^{1/3}$

(1) I-E; II-D; III-A; IV-B (2) I-D; II-E; III-C; IV-A
(3) I-D; II-B; III-E; IV-A (4) I-E; II-B; III-D; IV-C

38. Match the angle of contact for a liquid with suitable options in list II :

List-I		List-II	
I	0°	A	liquid will rise
II	= 90°	B	pure water silver
III	< 90°	C	liquid will not wet solid surface
IV	> 90°	D	pure water and glass

(1) I-B; II-D; III-A; IV-C
(2) I-D; II-B; III-A; IV-C
(3) I-B; II-D; III-C; IV-A
(4) I-D; II-B; III-C; IV-A

ANSWER KEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	2	4	1	1	3	2	2	3	4	4	4	1	2	4	1
Que.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Ans.	2	1	1	3	4	3	4	4	4	3	1	4	2	3	1
Que.	31	32	33	34	35	36	37	38							
Ans.	4	1	3	1	1	3	4	2							

CO-EFFICIENT OF VISCOSITY OF A GIVEN VISCOUS LIQUID BY MEASURING TERMINAL VELOCITY OF A GIVEN SPHERICAL BODY

Introduction :

Viscosity is the property of a fluid (liquid or gas) by virtue of which it opposes the relative motion between its adjacent layers. It is the fluid friction or internal friction.

The internal tangential force which tends to retard the relative motion between the adjacent layers is called viscous force.

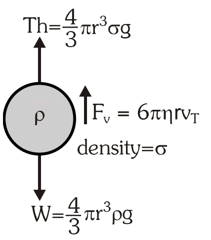
Stoke's Law and Terminal velocity

- **Stoke's Law**

Stoke showed that if a small sphere of radius r is moving with a velocity v through a homogeneous stationary medium (liquid or gas), of viscosity η then the viscous force acting on the sphere is $\mathbf{F_v = 6\pi\eta rv}$.

- **Terminal Velocity**

When a solid sphere falls in a liquid, its accelerating motion is controlled by the viscous force due to liquid and hence it attains a constant velocity which is known as the *terminal velocity* (v_T).



As shown in the figure when the body moves with constant velocity i.e. terminal velocity (with no acceleration) the net upward force (upthrust Th + viscous force F_v) balances the downward force (weight of the body W).

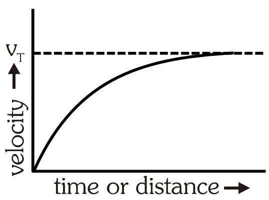
Therefore $\quad Th + F_v = W \Rightarrow \frac{4}{3}\pi r^3\sigma g + 6\pi\eta r v_T = \frac{4}{3}\pi r^3\rho g \Rightarrow v_T = \frac{2}{9}\frac{r^2(\rho-\sigma)}{\eta}g$

where r = radius of body $\qquad$ ρ = density of body

σ = density of medium $\qquad$ η = coefficient of viscosity.

Graph :

The variation of velocity with time (or distance) is shown in the adjacent graph.



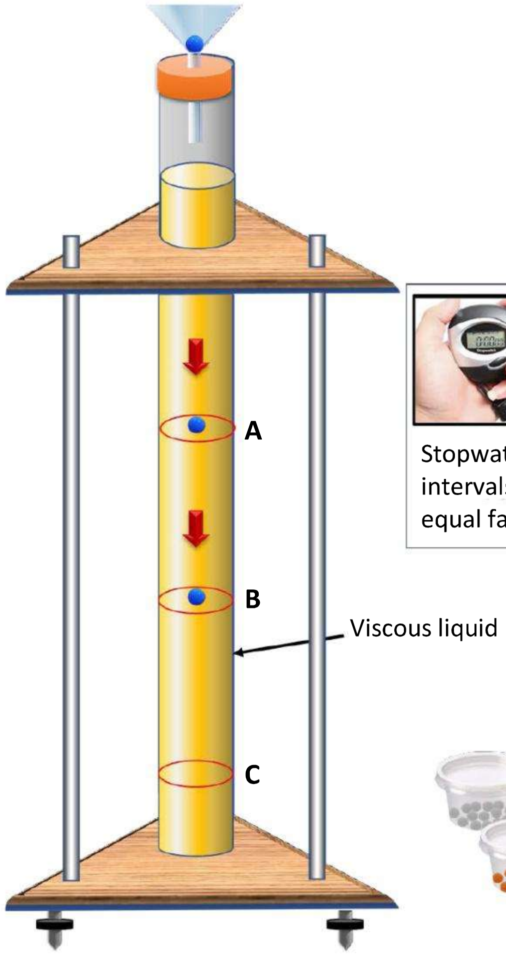
Examples of bodies moving in viscous medium :

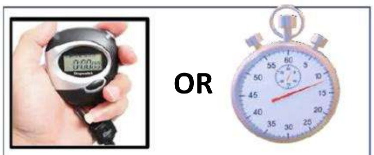
1. A balloon filled with He or H_2 moves up with constant rate in air due to viscosity.
2. A lead ball fall in long glycerine tube downwards with constant velocity due to viscosity.
3. A parachute falls down with small terminal velocity due to viscosity.

EXPERIMENT TO DETERMINE COEFFICIENT OF VISCOSITY USING STOKE'S LAW

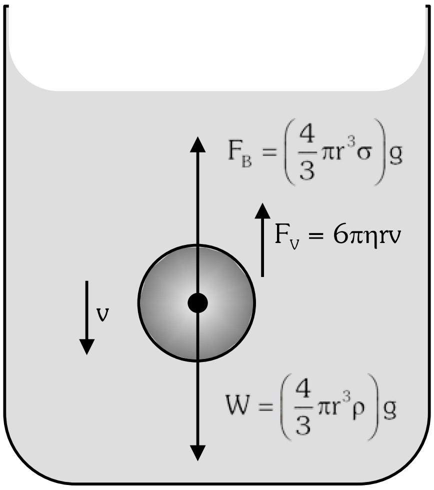
Objective: - To determine the coefficient of viscosity of a given viscous liquid by measuring the terminal velocity of a given spherical body, using stokes law.

Apparatus and material required :- A tall cylinder about 1m high of transparent glass/acrylic, lead shots of different sizes, stop watch (mechanical/electronic), laboratory stand, gummed paper, metre rod, thermometer, glycerine etc.





Stopwatch to know time intervals between successive equal falling distances



Forces acting on a spherical body falling through a viscous medium according to Stoke's law

Principle :

When a spherical body of radius r and density ρ falls freely through a viscous liquid of density σ and viscosity η, with terminal velocity v, then the sum of the upward buoyant force and viscous force F, is balanced by the downward weight of the ball (Fig.).

weight = Buoyant force on the ball + viscous force

$$\frac{4}{3}\pi r^3 \rho g = \frac{4}{3}\pi r^3 \sigma g + 6\pi\eta r v$$

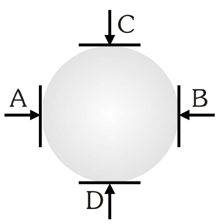
or $$= \frac{2}{9}\frac{r^2(\rho-\sigma)g}{\eta}$$

where v is the terminal velocity, the constant velocity acquired by a body while moving through viscous fluid under application of constant viscous force.

The terminal velocity depends directly on the square of the size (diameter) of the spherical ball. Therefore, if several spherical balls of different radii are made to fall freely through the viscous liquid then a plot of v vs r^2 would be a straight line.

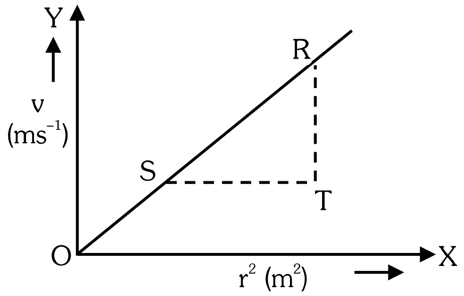
Procedure :

1. Fit a rubber cork in the mouth of the glass jar after filling it with glycerine and pass the small tube through it.
   Paste two pieces of gummed paper at two points separated by about 50 cm and measure the distance.
2. Now take a lead shot of such a size that it can easily pass through the glass tube. Measure its diameter with a screw gauge in two mutually perpendicular directions and take its mean.



Diameter of lead shot measured in two mutually perpendicular directions

3. Dip the ball in a small quantity of glycerine and drop it through the narrow glass tube so that it falls centrally through the glass jar. After moving through a few centimeters, the ball will attain a uniform velocity. As soon as the ball passes down the upper edge of the first gummed paper, start the stop watch and stop it when it reaches the upper edge of the next gummed paper. From this, find the velocity of the sphere.
4. Repeat the experiment by dropping three or four lead shots of the same size in quick succession to ensure identical temperature conditions and find the mean value of v.
5. Repeat the experiment by dropping five more lead shots of different sizes.



Graph between terminal velocity and square of radius of ball, r^2

Precautions :

1. The liquid should be highly viscous and transparent.
2. Ball should be perfectly spherical.
3. The lead shots should be dropped gently and the falling lead shots should not touch the walls of the glass tube.
4. Velocity should be noted only when it becomes constant.

Sources of Error :

1. The liquid may not have uniform density.
2. Screw gauge may have some type of error.
3. The temperature of liquid may not constant which appreciable affects viscosity.
4. There may be some delay or error in calculating terminal velocity.

Facts and applications of viscosity ;

1. Millikan conducted the oil drop experiment, to determine the charge of an electron. He used the knowledge of viscosity to determine charge.
2. Viscosity plays important role in printing process, painting and spraying.
3. Highly viscous liquids are used to damp the motion of some instruments, doors and are used as brake oil in hydraulic brakes.
4. The knowledge of the coefficient of viscosity and its variation with temperature, helps to choose suitable lubricants for machines depending upon operating conditions.

Further activities :

1. To find viscosity of mustard oil [Hint: Set up the apparatus and use mustard oil instead of glycerine in the wide bore tube].
2. To check purity of milk [Hint: Use mustard oil in the tall tube. Take an eye dropper, fill milk in it. Drop one drop of milk in the oil at the top of the wide bore tube and find its terminal velocity. Use the knowledge of coefficient of viscosity of mustard oil to calculate the density of milk].
3. Study the effect of viscosity of water on the time of rise of air bubble [Hint: Use the bubble maker used in an aquarium. Place it in the wide bore tube. Find the terminal velocity of rising air bubble].

MULTIPLE CHOICE QUESTIONS

1. The velocity of falling rain drop attain limiting value because of :-
(1) surface tension
(2) upthrust due to air
(3) viscous force exerted by air
(4) none of these

2. Poise is the unit of :-
(1) Pressure (2) Friction
(3) Surface tension (4) Viscosity

3. A body of density D_1 and mass M is moving downward with uniform velocity in glycerine of density D_2. What is the viscous force acting on it:-
(1) $Mg\left(1-\frac{D_2}{D_1}\right)$ (2) $Mg\left(1-\frac{D_1}{D_2}\right)$
(3) Mg D_1 (4) Mg D_2

4. Two small spheres of radii r and 4r fall through a viscous liquid with the same terminal velocity. The ratio of the viscous forces acting on them is:-
(1) 1:2 (2) 4:1 (3) 1:16 (4) 1:4

5. A small drop of water falls from rest through a large height h in air. The final velocity is :-
(1) almost independent of h
(2) proportional to $\sqrt{h}$
(3) proportional to h TG: @NEETxNOAH
(4) inversely proportional to h

6. Two drops of equal radius are falling through air with a steady velocity of 1 cm/s. If the two drops coalesce, then its terminal velocity will be :-
(1) $4^{1/3}\times 5\,cm/s$ (2) $4^{1/3}$ cm/s
(3) $5^{1/3}\times 4\,cm/s$ (4) $4^{2/3}\times 5\,cm/s$

7. Speed of 4 cm radius ball in a viscous liquid is 40 cm/s. Then the speed of 2 cm radius ball of same material in the same liquid is :-
(1) 5 cm/s (2) 10 cm/s
(3) 40 cm/s (4) 80 cm/s

8. Two rain drops falling through air have radii in the ratio 3 : 2. They will have terminal velocity in the ratio :-
(1) 4 : 1 (2) 9 : 4 (3) 2 : 1 (4) 4 : 9

9. A sphere of mass M and radius R is falling in a viscous fluid. The square of the terminal velocity attained by the falling object will be proportional to :-
(1) MR^2 (2) M/R (3) M^2/R^2 (4) M/R^2

10. A drop of water of radius 0.0015 mm is falling in air. If the coefficient of viscosity of air is 2.0×10^{-5} kg / (m-s), the terminal velocity of the drop will be (neglect density of air) :-
(The density of water = 1.0×10^3 kg/m^3 and g = 10 m/s^2)
(1) 1.0×10^{-4} m/s (2) 2.0×10^{-4} m/s
(3) 2.5×10^{-4} m/s (4) 5.0×10^{-4} m/s

11. Two rain drops reach the earth with different terminal velocities having ratio 9 : 4. Then, the ratio of their volume is :-
(1) 3 : 2 (2) 4 : 9 (3) 9 : 4 (4) 27 : 8

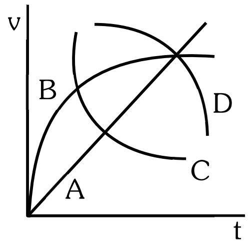
12. Viscosity of liquids :-
(1) Increases with increase in temperature
(2) Is independent of temperature
(3) Decreases with decrease in temperature
(4) Decreases with increase in temperature

13. A small sphere of radius 'r' falls from rest in a viscous liquid. As a result, heat is produced due to viscous force. The rate of production of heat when the sphere attains its terminal velocity, is proportional to :-
(1) r^3 (2) r^2 (3) r^5 (4) r^4

14. Two small spherical metal balls, having equal masses, are made from materials of densities ρ_1 and ρ_2($\rho_1 = 8\rho_2$) and have radii of 1mm and 2mm, respectively. They are made to fall vertically (from rest) in a viscous medium whose coefficient of viscosity equals η and whose density is 0.1 ρ_2. The ratio of their terminal velocities would be :-
(1) $\frac{79}{72}$ (2) $\frac{19}{36}$ (3) $\frac{39}{72}$ (4) $\frac{79}{36}$

15. The velocity of a small ball of mass M and density d, when dropped in a container filled with glycerine becomes constant after some time. If the density of glycerine is $\frac{d}{2}$, then the viscous force acting on the ball will be :
(1) $\frac{Mg}{2}$ (2) Mg
(3) $\frac{3}{2}Mg$ (4) 2Mg

16. A spherical ball is dropped in a long column of a highly viscous liquid. The curve in the graph shown, which represents the speed of the ball (v) as a function of time (t) is :



(1) B (2) C (3) D (4) A

17. The correct statement about the variation of viscosity of fluid with increase in temperature:
(1) viscosity of both liquids and gases increases
(2) viscosity of liquids increases
(3) viscosity of liquids decreases
(4) viscosity of gases decreases

18. The terminal velocity of a copper ball of radius 5 mm falling through a tank of oil at room temperature is 10 cm s^{-1}. If the viscosity of oil at room temperature is 0.9 kg m^{-1} s^{-1}, the viscous drag force is :
(1) 8.48×10^{-3} N (2) 8.48×10^{-5} N
(3) 4.23×10^{-3} N (4) 4.23×10^{-6} N

19. If the terminal velocity of a sphere of gold (density = 19.5 kg/m^3) is 0.8 m/s in a viscous liquid (density = 1.5 kg/m^3), find the terminal speed of a sphere of silver (density=10.5 kg/m^3) of the same size in the same liquid :-
(1) 0.4 m/s (2) 0.133 m/s
(3) 0.1 m/s (4) 0.2 m/s

20. Two rubber ball with radii in the ratio of 1 : 2 fall from a great height through the atmosphere, then the ratio of their momentum after they have attained terminal velocity is :-
(1) 1 : 1 (2) 1 : 4 (3) 1 : 16 (4) 1 : 32

21. Consider the following two statements A and B, and identify the correct choice in the given answers :
A : Viscosity of liquids decreases with decrease in temperature
B : Surface tension of a liquid decreases with increase in temperature
(1) Both A and B are true
(2) A is true but B is false
(3) A is false but B is true
(4) Both A and B are false

22. A small ball of mass m and radius r is falling under gravity through a viscous liquid of coefficient of viscosity η. If g is the acceleration due to gravity then the terminal velocity of the ball is proportional to
(1) $\frac{mg\eta}{r}$ (2) $mg\eta r$ (3) $\frac{mgr}{\eta}$ (4) $\frac{mg}{r\eta}$

23. A sphere of brass released in a long liquid column attains a terminal velocity v_0. If the terminal velocity attained by sphere of marble of the same radius and released in the same liquid is nv_0. Then the value of n will be: (given the specific gravity of brass, marble and liquid are 8.5, 2.5 and 0.8 respectively.)
(1) $\frac{5}{17}$ (2) $\frac{17}{77}$
(3) $\frac{11}{31}$ (4) $\frac{17}{5}$

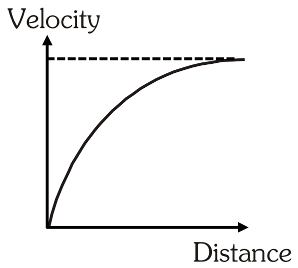
24. Two metal spheres are falling through a liquid of density 2×10^3 kg/m^3 with the same uniform speed. The material density of sphere 1 and sphere 2 are 8×10^3 kg/m^3 and 11×10^3 kg/m^3 respectively. The ratio of their radii is :-
(1) $\frac{11}{8}$ (2) $\sqrt{\frac{11}{8}}$ (3) $\frac{3}{2}$ (4) $\sqrt{\frac{3}{2}}$

25. ***Assertion :-*** Viscosity of a liquid is the property of the liquid by virtue of which it opposes the relative motion among its different layers.
Reason :- The viscosity of liquid increases rapidly with rise in temperature.
(1) Both (A) and (R) are true and (R) is the correct explanation of (A).
(2) Both (A) and (R) are true and (R) is NOT the correct explanation of (A).
(3) (A) is true but (R) is false.
(4) (A) is false but (R) is true.

26. ***Assertion :*** Machine parts are jammed in winter.
Reason : The viscosity of lubricant used in machine parts increases at low temperature.
(1) Both (A) and (R) are true and (R) is the correct explanation of (A).
(2) Both (A) and (R) are true and (R) is NOT the correct explanation of (A).
(3) (A) is true but (R) is false.
(4) (A) is false but (R) is true.

27. ***Assertion :*** A small spherical ball is dropped in a viscous liquid. The velocity of liquid is shown in figure.

Reason : The value of acceleration due to gravity in viscous liquid first increases then becomes constant.



(1) Both (A) and (R) are true and (R) is the correct explanation of (A).
(2) Both (A) and (R) are true and (R) is NOT the correct explanation of (A).
(3) (A) is true but (R) is false.
(4) (A) is false but (R) is true.

ANSWER KEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	**3**	**4**	**1**	**4**	**1**	**2**	**2**	**2**	**3**	**3**	**4**	**4**	**3**	**4**	**1**
Que.	16	17	18	19	20	21	22	23	24	25	26	27			
Ans.	**1**	**3**	**1**	**1**	**4**	**3**	**4**	**2**	**4**	**3**	**1**	**3**			

SPEED OF SOUND IN AIR AT ROOM TEMPERATURE USING A RESONANCE TUBE

KEY POINTS :

Resonance tube experiment :

Apparatus:

It has a 100 cm long glass or brass tube AB of about 2.5 cm internal diameter. The tube is fixed on a vertical board along the side of a metre scale marked in millimeters. The zero of the scale coincides with the upper end of the tube. The lower end of the glass tube is drawn out and is connected to a reservoir of water with the help of rubber tubing. A pinch cock is attached with the rubber tubing. The water level in the resonance tube AB, can be adjusted by manipulating the adjustable screw attached with the reservoir for clamping . To find adjustments of the water level in the tube AB, the pinch-cock is used. The tube AB can be made vertical with the help of the levelling screws SS provided at the heavy base of the frame.

End correction:

It is found that antinode occurs slightly above the open end of the resonance tube. So a small correction has to be applied to the observed resonant length of the air column. This correction is called end correction. Theoretically, it was found by lord Rayleigh and it is 0.3D or 0.6 R, where D is diameter and R is radius of the tube.

EXPERIMENT

Objective :- To find the speed of sound in air at room temperature using a resonance tube by two resonance positions.

Apparatus required :- Resonance tube apparatus, tuning forks of different frequencies, a rubber pad, a thermometer, a set square, a spirit level etc.

Principle:-

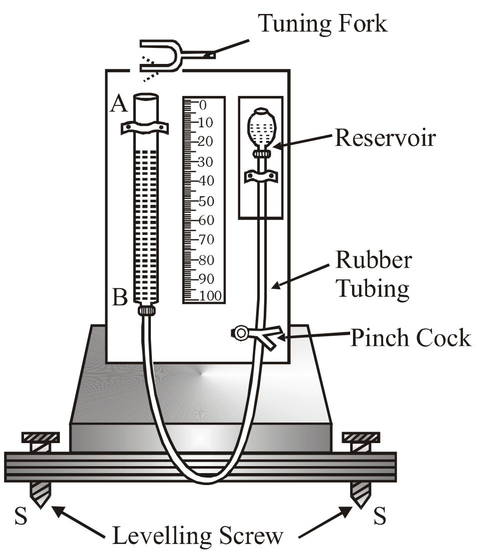
If ℓ_1 and ℓ_2 are the lengths of the air columns for the first and the second positions of resonance respectively,

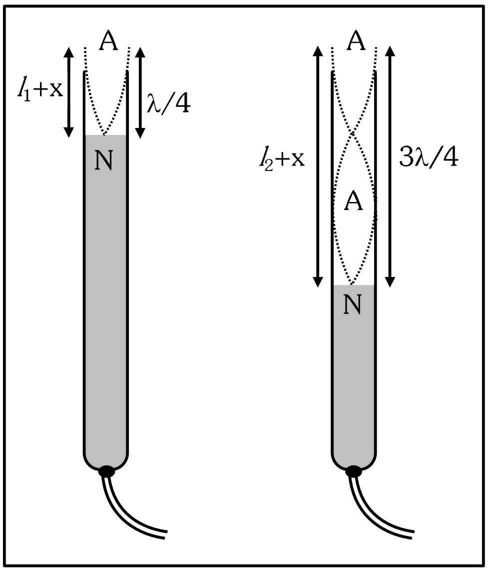
$$\ell_1 + x = \lambda/4 \quad .....(i)$$

and $$\ell_2 + x = 3\lambda/4 \quad .....(ii)$$

x = end correction ; λ = wavelength of the sound wave.

So, $\ell_2 - \ell_1 = \dfrac{\lambda}{2}$





or $\lambda = 2(\ell_2 - \ell_1) \Rightarrow \because v = n\lambda$

where v and n are the velocity and frequency of the sound wave respectively.

So, $v = 2n(\ell_2 - \ell_1)$

The velocity at 0°C is given by,

$v_0 = (v_t - 0.61 \times t)$ in ms^{-1} where v_t is velocity at room temperature t°C.

Also by eliminating λ from equations (i) and (ii), the end correction. $x = \frac{\ell_2 - 3\ell_1}{2}$

Procedure :

1. With the help of the plumb line and the levelling screws at the base, set the resonance tube AB vertical. Fill water in the reservoir R and some portion of the resonance tube.
   Suspend the thermometer by the side of the resonance tube to note the room temperature.
2. Release the pinch-cock and adjust the level of water in the resonance tube near the end A by adjusting the position of the reservoir R and then, after closing the pinch-cock lower down the position of the reservoir R.
3. Strike the tuning fork gently on the rubber pad and place it just above the upper end A of the resonance tube so that the prongs of the vibrating tuning fork are in vertical plane. Now open then pinch-cock and let the water level fall in the resonance tube slowly. At some position of the water level, you will listen sound of increasing loudness.
4. Repeat above steps to get the the exact position of water level in the resonance tube for which the sound is of maximum intensity. Note the position of the water level with the help of a set square keeping one of its perpendicular edges tangential to meniscus of water and other edge parallel to line of graduations on the metre scale. Note the length ℓ_1 of the resonance column as shown in figure. This position corresponds to the first resonance position. Confirm the resonance positions by taking four readings, two when the level of water is falling and the other two when the water level is rising. Note down these lengths of the air column as ℓ_1.
5. Lower the position of water level so that air column increased about three times the length ℓ_1. Repeat above steps to get the second position of resonance with the same tuning fork. Note this length ℓ_2 of air column.

Precautions :

1. The resonance tube should be set vertical using levelling screw.
2. Tuning fork should be vibrated gently by a rubber pad.
3. Prongs should be vibrated in a vertical plane just above the mouth (end) of the resonance tube.
4. Readings should be taken for water level rising as well as water level falling in the tube.
5. While measuring air temperature, thermometer bulb should not touch water or sides of resonance tube.

MULTIPLE CHOICE QUESTIONS

Passage

A cylindrical pipe of length 45cm closed at one end is found to be at resonance when a tuning fork of frequency 512 Hz is sounded near the open end of the pipe.

(Speed of sound is 332 m/s)

1. The mode of vibration of air in tube is :-

(1) Fundamental mode

(2) First overtone

(3) Second overtone

(4) Third overtone

2. The value of end-correction is –

(1) 3.2 (2) 3.4 (3) 3.6 (4) 3.8

3. Estimate the diameter of the pipe using Rayleigh criterion-

(1) 12 cm (2) 22 cm

(3) 1.2 cm (4) 2.2 cm

Passage

The velocity of sound in air is measured by using resonance tube method. The observation made during the experiment are as follows –

Frequency of first tuning fork f_1 = 480 Hz

Frequency of second tuning fork f_2 = 512 Hz

Position of upper end of the tube, L_1 = 0.2 cm

Room temperature T = 25°C

Frequency of tuning fork	Position of water level at resonance L_2(cm)				Mean length of air column L_2–L_1 (cm)
	Resonance	Water falling	Water rising	Mean L_2	
480	First	17.0	17.2		ℓ_1 =
	Second	52.4	52.6		ℓ_2 =
512	First	16.4	16.2		ℓ_1' =
	Second	49.9	50.1		ℓ_2' =

4. The velocity of sound at room temperature

(1) 342.5 (2) 332.5

(3) 323.5 (4) 352.5

5. The end correction for the tube.

(1) 0.8 cm (2) 0.75 cm

(3) 0.77 cm (4) 0.9 cm

6. A tube closed at one end and containing air produces, when excited, the fundamental note of frequency 512 Hz. If the tube is open at both ends, the fundamental frequency that can be excited is (in Hz)

(1) 1024 (2) 512

(3) 256 (4) 128

7. An air column in pipe,which is closed at one end will be in resonance with a vibrating tuning fork of frequency 264 Hz if the length of the column in cm is : [v = 330 m/s]

(1) 31.25 (2) 62.50

(3) 110 (4) 125

8. Velocity of sound in air is 320 m/s. A pipe closed at one end has a length of 1 m neglecting end corrections, the air column in the pipe can resonant for sound of frequency.

(a) 80 Hz (b) 240 Hz

(c) 500 Hz (d) 400 Hz

(1) a (2) a,b (3) a,b,d (4) a,d

9. In a long cylindrical tube, the water level is adjusted and the air column above it is made to vibrate in unison with a vibrating tuning fork kept at the open end. Maximum sound is heard when the air column lengths are equal to

(1) $\frac{\lambda}{4},\frac{\lambda}{2},\frac{3\lambda}{4}$ (2) $\frac{\lambda}{2},\lambda,\frac{3\lambda}{2}$

(3) $\frac{\lambda}{2},\frac{3\lambda}{2},\frac{5\lambda}{2}$ (4) $\frac{\lambda}{4},\frac{3\lambda}{4},\frac{5\lambda}{4}$

10. If l_1 and l_2 are the lengths of air column for the first and second resonance when a tuning fork of frequency n is sounded on a resonance tube, then the distance of the displacement antinode from the top end of the resonance tube is:

(1) $2(l_2 - l_1)$ (2) $\frac{1}{2}(2l_1 - l_2)$

(3) $\frac{l_2 - 3l_1}{2}$ (4) $\frac{l_2 - l_1}{2}$

11. A tuning fork of frequency 340 Hz is vibrated just above a cylindrical tube of length 120 cm. Water is slowly poured in the tube. If the speed of sound in air is 340 m/s, then the minimum height of water required for resonance is

(1) 25 cm (2) 45 cm

(3) 75 cm (4) 95 cm

12. A student is experimenting with resonance tube apparatus in Physics lab to find the speed of sound at room temperature. He got resonating lengths of air column as 17 cm and 51 cm, using tuning fork of frequency 512 Hz. Find speed of sound at room temperature and specify, whether the side water reservoir was moved upward or downward to obtain the second resonance (51 cm)?

(1) 348 m/s, downwards
(2) 348 m/s, upwards
(3) 332 m/s, downwards
(4) 332 m/s, upwards

13. While measuring the speed of sound by performing a resonance column experiment, a student gets the first resonance condition at column length of 18 cm during winter. Repeating the same experiment during summer, student measures the column length to be x cm for the second resonance. Then

(1) $18 > x$ (2) $x > 54$
(3) $54 > x > 36$ (4) $36 > x > 18$

14. A tuning fork of frequency 480 Hz is used in an experiment for measuring speed of sound (v) in air by resonance tube method. Resonance is observed to occur at two successive lengths of the air column, ℓ_1 = 30 cm and ℓ_2 = 70 cm. Then v is equal to :

(1) 332 ms^{-1} (2) 379 ms^{-1}
(3) 384 ms^{-1} (4) 338 ms^{-1}

15. A student is performing the experiment of resonance column. The diameter of the column tube is 6cm. The frequency of the tuning fork is 504 Hz. Speed of the sound at the given temperature is 336 m/s. The zero of the meter scale coincides with the top end of the resonance column tube. The reading of the water level in the column when the first resonance occurs is:

(1) 13 cm (2) 16.6 cm
(3) 18.4 cm (4) 14.9 cm

16. In an experiment to determine the velocity of sound in air at room temperature using a resonance is observed when the air column has a length of 20.0 cm for a tuning fork of frequency 400 Hz is used. The velocity of the sound at room temperature is 336 ms^{-1}. The third resonance is observed when the air column has a length of ____cm.

(1) 104 cm (2) 100 cm
(3) 90 cm (4) 80 cm

17. The first resonance length of a resonance tube is 17 cm and the second resonance length is 53 cm. The third resonance length of the tube will be :-

(1) 85 cm (2) 87 cm
(3) 88 cm (4) 89 cm

ANSWER KEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	2	3	1	1	3	1	1	3	4	3	2	1	2	3	4
Que.	16	17													
Ans.	1	4													

SPECIFIC HEAT CAPACITY OF A GIVEN (I) SOLID AND (II) LIQUID BY METHOD OF MIXTURES

EXPERIMENT (A)

Objective : To determine specific heat of a given solid (lead shots) by methods of mixture.

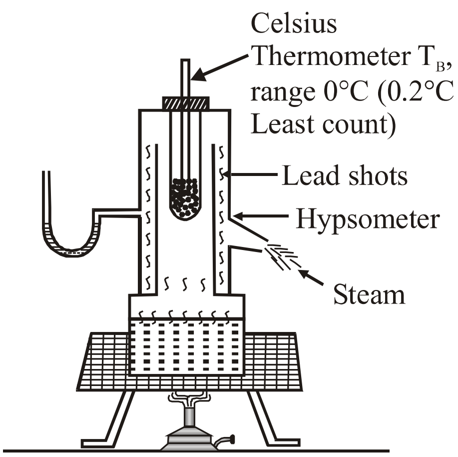
Apparatus required : Solid (lead shots), copper calorimeter with copper stirrer and lid, calorimeter jacket (wooden box with coating of insulating material inside), hypsometer, heating arrangement tripod, burner and wire gauge or a hot plate, Celsius thermometers, physical balance, weight box and milligram fractional weights etc.

Principle: Law of mixtures **Heat gained by cold substance = Heat loss by hot substance**

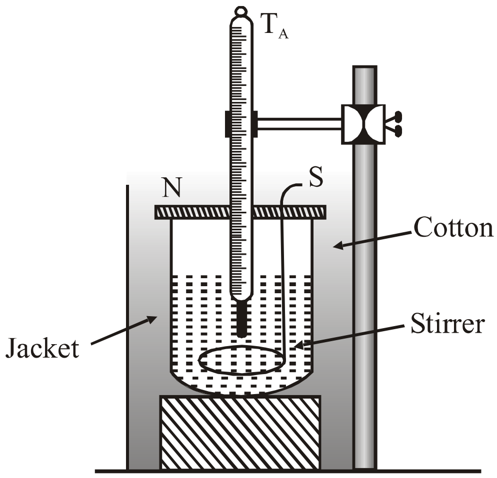
(Assuming no heat loss to the atmosphere)

Procedure :

1. Take about 100 grams of lead shots in the tube of hypsometer and add sufficient quantity of water in the hypsometer. Insert the thermometer marked T_B in the tube such that its bulb is surround by lead shots and fix the tube inside the mouth of hypsometer.
2. Place the hypsometer on the wire gauze, placed on the tripod and start heating it, using the burner.
3. Weight the calorimeter with stirrer and lid. Record it as m_1.
4. Place few pieces of ice in a beaker containing water such that its temperature becomes 5 to 7°C below the room temperature. Fill 2/3 of the calorimeter with cold water from the beaker and ensure that no moisture from air should condense on the surface of the calorimeter, clean the surface if drops appear. Weigh the calorimeter with stirrer, lid and water in it, record it as m_2.



Hypsometer for generating steam and heating the given solid



Calorimeter containing known mass of water, stirrer and a thermometer placed inside a jacket

5. Put calorimeter in the jacket and insert thermometer T_A through the lid cover of calorimeter and hold it in a clamp provided on the jacket such that the bulb of thermometer is well immersed in water but does not touch the bottom of the calorimeter. Note and record the temperature of water in the calorimeter.
6. See the temperature of the solid in hypsometer at intervals of two minutes till the temperature becomes steady. As the temperature becomes steady for about 5 minutes, record it as θ_2 .

7. Note the temperature of cold water in the calorimeter once again. This is to be taken as the reading for calculations. Immediately after this, remove the cork along with thermometer from the copper tube of hypsometer. Take out the tube, raise the lid of calorimeter and transfer the hot solid quickly to water in the calorimeter without any splash of water.
8. Stir the water in the calorimeter till the temperature of the mixture becomes steady. Note the equilibrium temperature reached by the hot solid and the cold water in the calorimeter.
9. Gently take the thermometer out of the water in the calorimeter. Take care that no water drops come out of the calorimeter along with the thermometer. Take out the calorimeter from the jacket and weight the calorimeter with stirrer, lid, water and solid in it. Record it as m_3.

Observations and calculations :

Mass of calorimeter + stirrer + lid = m_1 g.
Mass of calorimeter + lid + cold water = m_2 g.
Temperature of cold water in calorimeter = θ_1 °C.
Steady temperature of solid in hypsometer by thermometer B = θ_2 °C.
Final, i.e., equilibrium temperature of the mixture θ_e °C.
Mass of calorimeter + stirrer + lid + water + solid = m_3 g.

Water equivalent of calorimeter + stirrer, W = m (Mass of calorimeter) $\times \frac{S_C}{S_W}$

Applying law of mixtures, keeping in view the conditions,
Heat lost = Heat gained

$(m_3 - m_2) \times S(\theta_2 - \theta_e) = (m_w + W) \times S_w (\theta_e - \theta_1)$

$$\therefore \quad S = \frac{(m_w + W)}{(m_3 - m_2)} \frac{(\theta_e - \theta_1).S_w}{(\theta_2 - \theta_e)} \text{ J/gm/°C}$$

EXPERIMENT (B)

Objective :- To determine the specific heat of a given liquid (kerosene or turpentine oil) by method of mixtures.

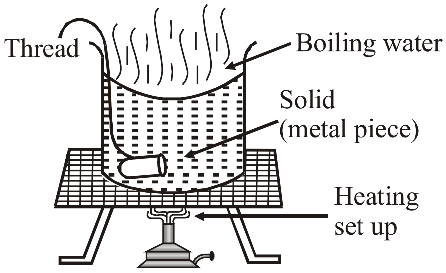
Apparatus required :- A calorimeter with stirrer and lid cover, the lid cover having provision of two holes for passing thermometer and stirrer, jacket for calorimeter, thermometer, given liquid (it should be non-volatile) kerosene oil or turpentine oil, cylindrical piece of metal (about 6 to 8 cm long and about 1 cm diameter), cotton thread about 20 cm long to tie the metal piece with it and it should be non-slipping, beaker with water, tripod stand, wire gauze, burner or hot plate, physical balance and weight box with fractional weights etc.

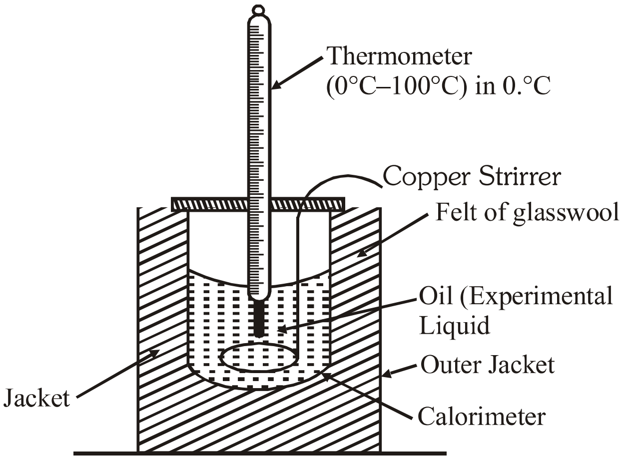
Principle: Law of mixtures $\boxed{\textbf{Heat gained by cold substance = Heat loss by hot substance}}$

(Assuming no heat loss to the atmosphere)

Procedure :

1. Set the beaker, tripod, wire gauze and burner as shown and fill the beaker to half of its volume with tap water and start heating the water.
2. Affix the cylindrical metal piece tightly using one end of machine thread. The thread should not slip from the piece and about 10 cm of thread is therefore suspending the metal piece in water.
3. Weight the calorimeter with stirrer, in physical balance. Record its mass as m_1.
4. Fill the calorimeter (3/4) with given liquid whose specific heat is to be determined. Weigh the calorimeter + stirrer + given liquid (oil). Record the mass as m_2.





5. Read the temperature of oil in the colorimeter and record it as θ_1 °C.
6. Take the metal piece and weigh it in physical balance. Record the mass as m_3.
7. The metal piece is suspended by thread and placed in the beaker of water. Start heating the water and boil it with metal piece inside for about 20 minutes.
8. When the sample has been in boiling water for enough time duration (say 15 minutes) such as to attain temperature of boiling water (100°C), once again note the temperature of oil in the calorimeter, lift the metal piece by thread and transfer it quickly to the calorimeter.
9. The jacket of calorimeter is held close to the hot water bath and sample of metal is transferred quickly without splashing any oil. Give metal piece a little shake to remove any adhering hot water just before transferring it to liquid.
10. The lid cover is kept over the calorimeter immediately after transfer of hot solid in the oil and the mixture is well stirred till final steady temperature (equilibrium temperature is reached). Record the equilibrium temperature as θ_e .

Observations & Calculations :

Mass of calorimeter + stirrer, m_1 g

Mass of calorimeter + stirrer + oil, m_2 g

Temperature of oil in the calorimeter, θ_1 °C

Mass of the cylindrical piece tied to thread, m_3 g

Temperature of boiling water in the beaker, i.e. temperature of metal piece θ_2 = 100 °C.

Steady equilibrium temperature of mixture θ_e °C.

Water equivalent of calorimeter, $W = \text{mass} \times \dfrac{\text{Specific heat of material of calorimeter}}{\text{Specific heat of water}}$

Mass of oil m = $m_2 \times 0.095$ (for copper calorimeter)

Applying law of mixtures :

$(\theta_e - \theta_1)(W + mS_\ell) = m_3 \times S \times (100 - \theta_e)$

Specific heat of liquid $S_\ell = \dfrac{m_3.S(100-\theta_e)}{m(\theta_e-\theta_1)} - \dfrac{W}{m}$ (J gm^{-1}°C^{-1})

MULTIPLE CHOICE QUESTIONS

1. Equal amount of heat energy are transferred into equal mass of ethyl alcohol and water sample. The rise in temperature of water sample is 25°C. The temperature rise of ethyl alcohol will be. (Specific heat of ethyl alcohol is one half of the specific heat of water).
(1) 12.5°C
(2) 25°C
(3) 50°C
(4) It depends on the rate of energy transfer.

2. A block of mass 2.4 kg is heated to temperature of 500°C and placed on a large ice block. What is the maximum amount of ice that can melt (approx.). Specific heat for the block = 0.1 Cal/gm°C.
(1) 1 kg (2) 1.5 kg (3) 2 kg (4) 2.5 kg

3. 10 gm of ice at 0°C is kept in a calorimeter of water equivalent 10 gm. How much heat should be supplied to the apparatus to evaporate the water thus formed? (Neglect loss of heat)
(1) 6200 cal (2) 7200 cal
(3) 13600 cal (4) 8200 cal

4. 1 kg of ice at 0°C is mixed with 1 kg of steam at 100°C. What will be the composition of the system when thermal equilibrium is reached? latent heat of fusion of ice = 3.36×10^5 J/kg and latent heat of vaporization of water = 2.26×10^6 J/kg.
(1) 2000 g water
(2) 665 g steam and 1335 g water
(3) 665 g ice and 1335 g water
(4) 2000 g steam

5. A copper ball of mass 100 gm is at a temperature T. It is dropped in a copper calorimeter of mass 100gm, filled with 170 gm of water at room temperature. Subsequently, the temperature of the system is found to be 75°C. T is given by : (Given : room temperature = 30° C, specific heat of copper = 0.1 cal/gm°C)
(1) 1250°C (2) 825°C (3) 800°C (4) 885° C

6. The amount of heat required in converting 1 g ice at –10°C into steam at 100°C will be :–
(1) 3028 J (2) 6056 J (3) 721 J (4) 616 J

7. 2 kg ice at – 20°C is mixed with 5 kg water at 20°C. Then final amount of water in the mixture would be;
Given specific heat of ice = 0.5 cal/g°C,
Specific heat of water = 1 cal/g°C,
Latent heat of fusion for ice = 80 cal/g.
(1) 6 kg (2) 5 kg (3) 4 kg (4) 2 kg

8. The latent heat for vapourisation for 1 g water is 536 cal. Its value in Joule/kg will be :-
(1) 2.25×10^6 (2) 2.25×10^3
(3) 2.25 (4) None of these

9. If 10 g ice at 0°C is mixed with 10 g water at 20°C, the final temperature will be :-
(1) 50°C (2) 10°C (3) 0°C (4) 15°C

10. 420 joule of energy supplied to 10 g of water will raise its temperature by nearly :-
(1) 1°C (2) 4.2°C (3) 10°C (4) 42°C

11. Two liquids are at temperature 20°C and 40°C. When same mass of both of them is mixed the temperature of mixture is 32°C. What is ratio of their specific heat :-
(1) 1/3 (2) 2/3 (3) 1/5 (4) 2/5

12. 50 g of ice (latent heat 80 cal/g, at 0°C) is mixed with 50 g of water (specific heat 1 cal/g – °C) at 80°C. The final temperature of the mixture and final mass of water will be :-
(1) 0°C, 100 g (2) 40°C, 100 g
(3) 80°C, 50 g (4) < 0°C, 0 g

13. 10 g of ice at –20°C is added to 10 g of water at 50°C. Specific heat of water = 1 cal/g -°C, specific heat of ice = 0.5 cal/gm-°C. Latent heat of ice = 80 cal/g, the amount of ice in the mixture at the resulting temperature is :-
(1) 10 g (2) 5 g (3) 0 g (4) 20 g

14. 19 g of water at 30°C and 5 g of ice at –20°C are mixed together in a calorimeter. What is the final temperature of the mixture ? Given specific heat of ice = 0.5 cal g^{-1} $(°C)^{-1}$ and latent heat of fusion of ice = 80 cal g^{-1} :-
(1) 0°C (2) –5°C (3) 5°C (4) 10°C

15. 5 gm of steam at 100°C is passed into 6 gm of ice at 0°C. If the latent heats of steam and ice in cal per gm are 540 and 80 respectively, then the final temperature is :-
(1) 0°C (2) 100°C (3) 50°C (4) 30°C

ANSWER KEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	3	2	4	2	4	1	1	1	3	3	2	1	2	3	2

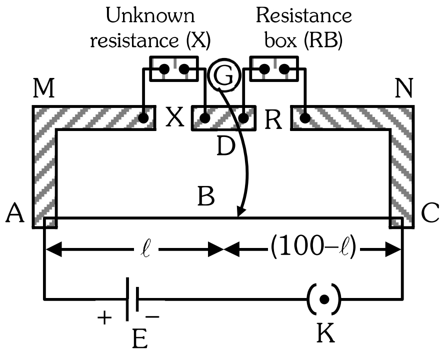
THE RESISTIVITY OF THE MATERIAL OF A GIVEN WIRE USING A METRE BRIDGE

Objective : To find resistivity of the material of a given wire using a meter bridge.

Apparatus required : A resistance box, a wire about 1 metre long (of the material whose specific resistance is to be determined), a metre bridge, a jockey, one- way key, a galvanometer, a battery eliminator or a cell, thick connecting wires, sand paper, screw gauge etc.

Principle: Meter bridge is based on principle of Wheat stone bridge.

Unknown resistance $X = R\left(\frac{\ell}{100-\ell}\right)$ and specific resistance of the material of the given wire, $\rho = \frac{XA}{L} = \frac{X(\pi r^2)}{L}$, where r and L are the radius and length of the given wire respectively.



Procedure :

1. Arrange the meter bridge and the various component as shown in figure and make tight connections. Putting RB in right gap and X in left gap
2. Take out the plug from RB to introduce a suitable resistance say, R = 2Ω and close the key K.
3. Now, touch the jockey on meter-bridge wire at different places to obtain such a position, where there is no deflection in the galvanometer. At this condtion

   AB = ℓ and BC = $(100 - \ell)$

   Putting RB in left gap and X in right gap
4. Repeat step 2 and 3. But in this balancing condition BC = ℓ and AB = $(100 - \ell)$
5. Now disconnect the unknown resistance wire from the circuit. Straighten it by stretching and remove any kinks and measure its length with the help of a meter scale.
6. Measure the diameter of the wire with the help of a screw gauge.

Precautions :

1. The connections should be neat, clean and tight.
2. All the plugs in the resistance box should be tight.
3. While moving the jockey to locate the balance point, the jockey should be lifted again and again and should not be pressed and slided on the wire throughout.
4. The plug in key K should be inserted only when the observations are to be taken.
5. The balance point should always be obtained near the midpoint or in between from 30 cm to 70 cm.
6. Diameter of wire should be measured in two mutually perpendicular direction at one place.

Source of error :

1. The plugs may not be clean.
2. The meter bridge wire may not have uniform cross-section.
3. Connections may be loose.
4. The screw gauge may have faulty calibration or backlash error.

MULTIPLE CHOICE QUESTIONS

1. Which of the following statement is True regarding Null point in finding resistance of unknown wire using Meter Bridge.

(i) At Null Point, current through galvanometer is zero.

(ii) At Null Point, condition is balanced Wheat stone bridge.

(iii) Deflection of galvanometer in same direction, either side of Null point.

(1) (i) only (2) (i) & (iii) (3) (i) & (ii) (4) All

2. Wheatstone bridge is an arrangement of _______ resistors used for accurate measurement of resistance.

(1) three (2) six (3) five (4) four

3. The resistivity of the material depends on :

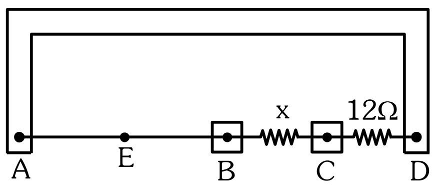
(1) Length of the wire

(2) Diameter of the wire

(3) Density of the wire

(4) Material of the wire

4. A thin uniform wire AB of length 1 m, an unknown resistance X and a resistance of 12Ω are connected by thick conducting strips as shown in figure. A battery and a galvanometer (with a sliding jockey connected to it) are also available. In the following diagram, connections are given to measure the unknown resistance X using the principle of Wheat stone bridge. The appropriate connections are:



(E is the balance point for wheat stone bridge)

(1) battery across EB and galvanometer across BC

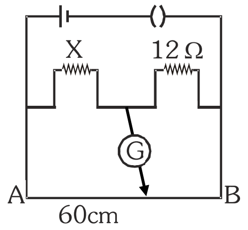
(2) battery across EC and galvanometer across BD

(3) battery across BD and galvanometer across EC

(4) battery across BC and galvanometer across CD

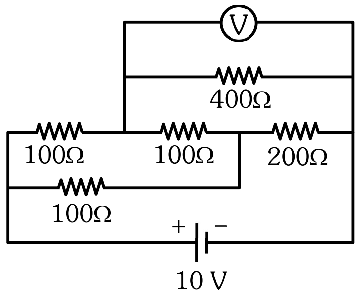
5. In meter bridge experiment, A thin uniform wire AB of length 1 m and unknown resistance x and a resistance of 12Ω are connected.

In the above question, after appropriate connection are made, it is found that no deflection takes places in the galvanometer where the sliding jockey touches the wire at a distance of 60 cm from A. What is the value of the resistance X ?



(1) 18Ω (2) 6Ω (3) 16Ω (4) 4Ω

6. For the electrical circuit shown in the figure, the potential difference across the resistor of 400Ω as will be measured by the voltmeter V of resistance 400 is ....



(1) $\frac{10}{3}$V (2) 4V (3) $\frac{20}{3}$V (4) 5V

7. In a simple metre-bridge circuit, the both gaps are bridge by coils P and Q having the smaller resistance. A balance is obtained when the jockey key makes contact at a point of the bridge wire 40 cm from the P end. On shunting the coil Q with a resistance of 50Ω the balance point is moved through 10 cm. What are the resistance of P and Q ?

(1) $\frac{100}{3}\Omega, \frac{100}{2}\Omega$ respectively

(2) $\frac{50}{3}\Omega, \frac{50}{2}\Omega$ respectively

(3) $\frac{25}{3}\Omega, \frac{25}{2}\Omega$ respectively

(4) $\frac{75}{3}\Omega, \frac{75}{2}\Omega$ respectively

8. What is the resistance of an open key ?

(1) $\propto$

(2) Can't be determined

(3) 0

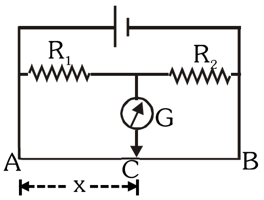
(4) depends on the other resistances

9. Resistance in the two gaps of a meter bridge are 10 ohms and 30 ohms respectively. If the resistances are interchanged, the balance point shifts by :–

(1) 33.3 cm (2) 66.67 cm

(3) 25 cm (4) 50 cm

10. In the shown arrangement of the experiment of a meter bridge if AC, corresponding to null deflection of galvanometer, is x then what would be its value if the radius of the wire AB is doubled:-

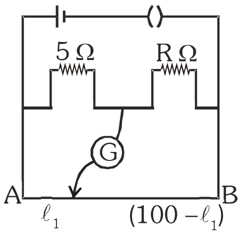


(1) x (2) $\frac{x}{4}$ (3) 4x (4) 2x

11. An unknown resistance R_1 is connected in series with a resistance of 10 Ω. This combination is connected to one gap of a metre bridge while a resistance R_2 is connected in the other gap. The balance point is at 50 cm. Now, when the 10 Ω resistance is removed the balance point shifts to 40 cm. The value of R_1 is (in ohms) :-

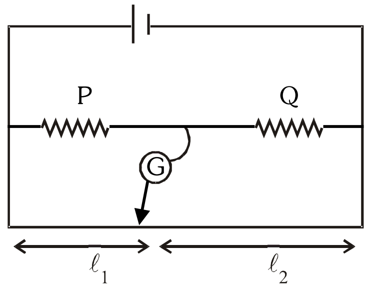
(1) 20 (2) 10 (3) 60 (4) 40

12. The resistance in the two arms of a meter bridge are 5 Ω and R Ω, respectively. When the resistance R is shunted with an equal resistance, the new balance point is at 1.6 ℓ_1. The resistance 'R' is :-



(1) 10 Ω (2) 15 Ω (3) 20 Ω (4) 25 Ω

13. The metre bridge shown is in balanced position with $\frac{P}{Q}=\frac{\ell_1}{\ell_2}$. If we now interchange the positions of galvanometer and cell, will the bridge work ? If yes, what will be balance condition ?



(1) yes, $\frac{P}{Q}=\frac{\ell_2-\ell_1}{\ell_2+\ell_1}$ (2) no, no null point

(3) yes, $\frac{P}{Q}=\frac{\ell_2}{\ell_1}$ (4) yes, $\frac{P}{Q}=\frac{\ell_1}{\ell_2}$

14. In a meter bridge set up, which of the following should be the properties of the one meter long wire?

(1) High resistivity and low temperature coefficient

(2) Low resistivity and low temperature coefficient

(3) Low resistivity and high temperature coefficient

(4) High resistivity and high temperature coefficient

15. In a meter bridge experiment, we try to obtain the null point at the middle. This

(1) reduces systematic error as well as random error.

(2) reduces systematic error but not the random error.

(3) reduces random error but not the systematic error

(4) reduces neither systematic error nor the random error

16. A student obtained following observations in an experiment of meter bridge to find unknown resistance of given wire :

S.No.	**R**	ℓ	**100 –** ℓ	$S=\left(\frac{100-\ell}{\ell}\right)R$
1	2Ω	43	57	2.65
2	3Ω	52	48	2.77
3	4Ω	58	42	2.89
4	5Ω	69	31	2.25

The most accurate value of unknown resistance will be

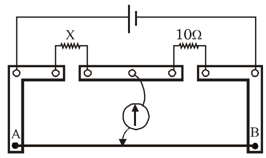
(1) 2.65 Ω (2) 2.77 Ω

(3) 2.89 Ω (4) 2.25 1

17. In a metre bridge experiment null point is obtained at 20 cm from one end of the wire when resistance X is balanced against another resistance Y. If X < Y, then where will be the new position of the null point from the same end, if one decide to balance a resistance of 4X against Y -

(1) 50 cm (2) 80 cm (3) 40 cm (4) 70 cm

18. A meter bridge is set-up as shown, to determine an unknown resistance 'X' using a standard 10 ohm resistor. The galvanometer shows null point when tapping-key is at 52 cm mark. The end-corrections are 1 cm and 2 cm respectively for the ends A and B. The determined value of 'X' is



(1) 10.2 ohm (2) 10.6 ohm
(3) 10.8 ohm (4) 11.1 ohm

ANSWER KEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	**3**	**4**	**4**	**3**	**1**	**3**	**2**	**1**	**4**	**1**	**1**	**2**	**4**	**1**	**1**
Que.	16	17	18												
Ans.	**2**	**1**	**2**												

THE RESISTANCE OF A GIVEN WIRE USING OHM'S LAW

Objective : To find resistance of wire using ohm's law –

Apparatus :

Unknown resistance wire, voltmeter, ammeter, rheostat, plug key, battery and connecting wires.

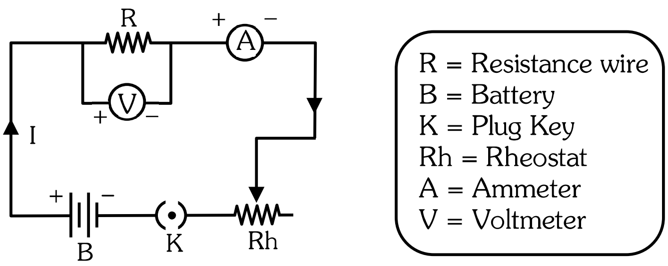
Principle :

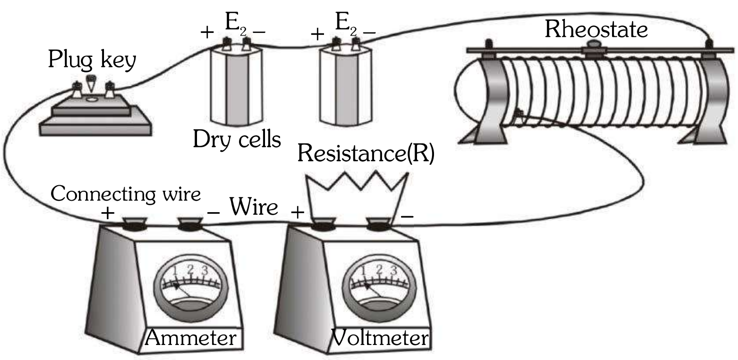
According to the **Ohm's law**, "the current flowing through a conductor is directly proportional to the potential difference applied across its ends provided the physical conditions (temperature, dimensions, pressure) of the conductor remains the same.

$$V \propto I \text{ or } V = RI$$

Formula $\boxed{R = \frac{V}{I}}$

Circuit Diagram :

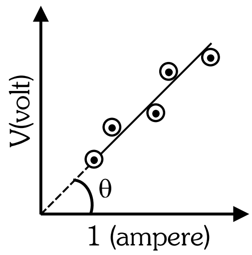




Procedure :

1. Draw the circuit diagram as shown in figure.
2. Note the range, the least count, and the zero error of voltmeter as well as that of the ammeter.
3. Insert the plug in key K. Slide the rheostat contact to the extreme right figure. So that the current passing through the resistance wire is minimum.
4. Adjust the rheostat and record the readings of the ammeter and the voltmeter. Then shift the rheostat contact to increase the current and note readings again. Take similarly ten observations.

Graph : Using the readings of voltmeter (V) and ammeter (I) draw a graph as straight line best fitting all the points.



Calculation : Slope of V–I curve = $\frac{\Delta V}{\Delta I}$ = $\tan\theta$ = R

Precautions :

1. Connections should be neat, clean and tight.
2. Connecting wires should be of thick copper wires.
3. Voltmeter and ammeter should be of proper range.
4. The key/plug should be inserted only while taking observations, otherwise current gives unnecessary heating of wires.
5. The unknown resistance should not be too low (than internal resistance of battery)
6. Ammeter is always connected in series in the circuit while voltmeter in parallel with the resistor.
7. Zero error in measuring instruments (voltmeter, ammeter) should be eliminated before taking observations.

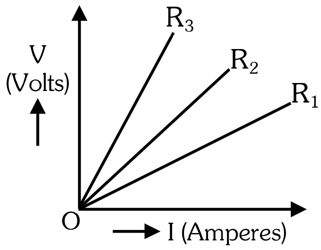
Sources of error :

1. Connections may be loose.
2. Rheostat may have very high resistance.
3. The unknown resistance may be too low.
4. Thick connecting wires may not be available.

MULTIPLE CHOICE QUESTIONS

1. The point to be kept in mind for verification of Ohm's law is
(1) ammeter and voltmeter should be connected in series
(2) ammeter should be connected in series and voltmeter in parallel
(3) ammeter should be connected in parallel and voltmeter in series
(4) more than one of the above

2. From the given V–I graphs for three resistors R_1, R_2 and R_3 it may be concluded that



(1) $R_1 > R_2 > R_3$ (2) $R_1 < R_2 < R_3$
(3) $R_1 = R_2 = R_3$ (4) None of the above

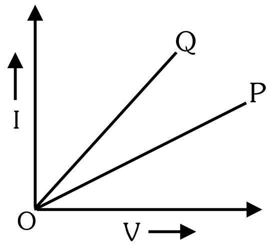
3. In an electric circuit, current becomes half when resistance is
(1) Removed
(2) Doubled
(3) Halved
(4) None of these

4. According to Ohm's Law, which of the following is true ?
(1) The current flowing through a wire is inversely proportional to its length
(2) The current flowing through a wire is directly proportional to its Resistance.
(3) The current flowing through a wire is directly proportional to the Potential Difference applied across its ends.
(4) The current flowing through the wire is inversely proportional to the Potential Difference applied across its ends.

5. Choose the CORRECT statement regarding Ohm's law:
(1) It is valid for any circumstances, i.e. independent of temperature
(2) Ohm's law is valid for all conducting materials
(3) The temperature must be constant for validation of this law
(4) All are wrong

6. The potential difference between the terminal of an electric heater is 60 V when it draws a current of 4 A from the source. What current will the heater draw if the potential difference is changed to 127.5 V ?
(1) 8.5 A (2) 24 A
(3) 10 A (4) 12 A

7. The I-V graphs for two different electrical appliances P and Q are shown in the diagram. If R_P and R_Q be the resistance of the devices, then



(1) $R_P = R_Q$ (2) $R_P > R_Q$
(3) $R_P < R_Q$ (4) $R_P = \frac{R_Q}{2}$

8. The current-voltage graph of ohmic devices is of the form :
(1) Parabolic curve
(2) Bi-linear curve
(3) Non-linear curve
(4) Linear curve

9. An ammeter is connected in ________ with the circuit.
(1) parallel
(2) series
(3) both parallel and series
(4) None of the above

10. The SI unit of electrical conductance is ________.
(1) Ohm
(2) Siemens
(3) Ohm meter
(4) Ampere

11. A wire of uniform cross-section A, length ℓ and resistance R is bent into a complete circle; the resistance between any two of diametrically opposite points will be :–
(1) $\frac{R}{2}$ (2) $\frac{R}{4}$
(3) $\frac{R}{8}$ (4) 4R

12. The electric resistance of a certain wire of iron is R. If its length and radius both are doubled, then :–

(1) the resistance will be halved and the specific resistance will remain unchanged

(2) the resistance will be halved and the specific resistance will be doubled

(3) the resistance and the specific resistance, will both remain unchanged

(4) the resistance will be doubled and the specific resistance will be halved.

13. When a piece of aluminium wire of finite length is drawn to reduce its diameter to half its original value, its resistance will become :-

(1) two times (2) four times

(3) eight times (4) sixteen times

14. As the temperature of a metallic resistor is increased, the product of resistivity and conductivity :-

(1) increases

(2) decreases

(3) may increase or decrease

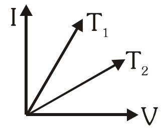
(4) remains constant.

15. The length of a given cylindrical wire is increased by 100%. Due to the consequent decrease in diameter the change in the resistance of the wire will be :–

(1) 300% (2) 200%

(3) 100% (4) 50%

16. The current voltage graph for a given metallic conductor at two different temperatures T_1 and T_2 are as shown in the figure. Then :–



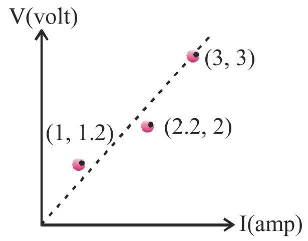
(1) $T_1 > T_2$

(2) $T_1 = T_2$

(3) nothing can be said about T_1 and T_2

(4) $T_1 < T_2$

17. In the measurement of resistance of a wire using Ohm's law, the plot between V and I is drawn as shown. The resistance of the wire is –



(1) 0.833 Ω (2) 0.9 Ω

(3) 1 Ω (4) None of these

ANSWER KEY

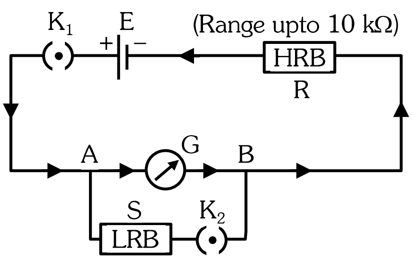
Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	2	2	2	3	3	1	2	4	2	2	2	1	4	4	1
Que.	16	17													
Ans.	4	3													

RESISTANCE AND FIGURE OF MERIT OF A GALVANOMETER BY HALF DEFLECTION METHOD

Objective : (a) To determine the resistance of a galvanometer by half deflection method and
(b) To find its figure of merit.

Apparatus required : A galvanometer, a battery or accumulator, a low resistance box (LRB), a high resistance box (HRB), two one-way keys, connecting wires etc.

Circuit diagram :

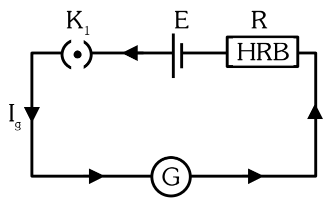


[Circuit diagram]

Theory and principle :

(a) **Resistance of galvanometer by half deflection method :** When a high resistance R is applied in the circuit with K_1 closed and K_2 open, the galvanometer draws a current I_g and shows a deflection θ such that

$$I_g = \frac{E}{R+G} \qquad \ldots(i)$$



where E, is emf of the battery and G is resistance of the galvanometer.

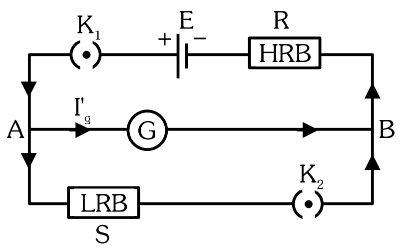
Now K_2 is closed. Adjust the resistance in LRB such that galvanometer deflection becomes equal to $\frac{\theta}{2}$.

Now the galvanometer draw the current.

$$I'_g = \frac{IS}{G+S} = \frac{ES}{R(G+S)+GS} \qquad \left(\text{where } I = \frac{E}{R+\frac{GS}{S}}\right)$$

Also $\qquad I'_g = \frac{1}{2}I_g$

$\therefore \qquad \frac{ES}{R(G+S)+GS} = \frac{1}{2}\cdot\frac{E}{R+G}$



gives $\qquad G = \frac{RS}{R-S}$

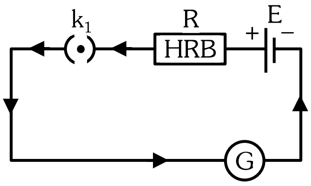
Knowing R and S, G can be calculated.

Also if R >> S, S can be dropped in comparison to R and then $\boxed{G \simeq S}$.

(b) **Figure of merit of galvanometer** is defined as the current required per division of deflection in galvanometer. It is denoted by k. Figure merit $k = \frac{I}{\theta}$

The circuit diagram for determination of figure of merit (k) of a galvanometer is shown in the figure.

When a high resistance R is introduced in the circuit through HRB, a small current I_g is drawn by it and it shows a deflection θ such that



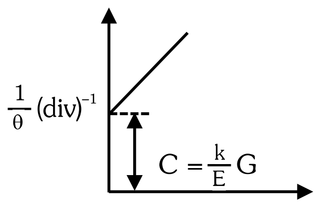
$$I_g = k\theta = \frac{E}{R+G}$$

$\Rightarrow$ Figure of merit $k = \frac{1}{\theta} \times \left(\frac{E}{R+G}\right)$ ...(ii)

Maximum current measured by galvanometer or full scale deflection current for galvanometer I_g = Number of division on one side of galvanometer scale $\times$ figure of merit

From equation (ii)

$$\frac{1}{\theta} = \frac{k}{E}R + \frac{k}{E}G \quad \text{...(iii)}$$



[Graph between (1/θ) and R]

$\therefore$ Graph between $\frac{1}{\theta}$ and R is as shown.

Procedure :

1. In the circuit, introduce a high resistance R in HRB and then insert the plug in the key K_1 Adjust the value of R to get deflection θ in even number of divisions.
2. Now close the key K_2 also and adjust the shunt resistance S from low resistance box (LRB) to get a deflection exactly half of half of reading obtain previously by galvanometer.
3. Repeat experiment for different values of R and θ.

Precautions:

1. All connections in the circuit should be neat, clean and tight.
2. All the plugs in HRB and LRB should be tight.
3. A very high resistance R from HRB should be introduced first and then key K_1 should be closed to avoid any over current damage in galvanometer.
4. The emf of the cell or battery should be constant.
5. The deflection in the galvanometer should be as large as possible and should be even number of divisions.

Sources of error :

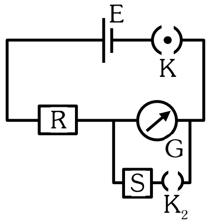
1. The plugs of HRB and LRB may not be clean
2. The emf of the battery may not be constant
3. The galvanometer divisions may not be uniform

MULTIPLE CHOICE QUESTIONS

1. The instrument __________ is used for detecting electric current is
(1) Galvanometer
(2) Tube tester
(3) Altimeter
(4) Fathometer

2. In half deflection method, a high resistance box is connected in series with the battery so that
(1) The deflection of the galvanometer is brought within the scale
(2) Power losses are minimized.
(3) High resistance values are easily available.
(4) None of the above.

3. While performing the galvanometer experiment using half deflection method, a student got almost the same value for S, every time, whatever be the value of R he had set in the (high value) resistance box. This is because



(1) The resistance box in which S is put, is Faulty
(2) Resistance G is very low
(3) In half-deflection method, current gets divided between G and S and R is very high.
(4) The internal resistance of the d.c source varies with current flow.

4. A moving coil galvanometer has 150 equal divisions, Its current sensitivity is 10 divisions per milliampere and voltage sensitivity is 2 divisions per millivolt. In order that each divisions reads 1 V, what will be the resistance in ohms needed to be connected in series with the coil ?
(1) 10^3 (2) 99995
(3) 9995 (4) 10^5

5. A galvanometer of resistance 200 Ω, gives full scale deflection for a current of 10^{-3} A. To convert it into an ammeter capable of measuring upto 1 A, what resistance should be connected in parallel with it ?
(1) $2\times10^{-1}\,\Omega$ (2) $2\,\Omega$
(3) $2\times10^{-3}\,\Omega$ (4) $2\times10^{-6}\,\Omega$

6. A galvanometer with resistance 100 Ω is converted into an ammeter with a resistance of 0.1 Ω, then galvanometer shows full scale deflection with current of 100 μA. Then what will be the minimum current in the circuit for full scale deflection of galvanometer ?
(1) 0.1001 mA (2) 100.1 mA
(3) 1000.1 mA (4) 1.001 mA

7. The range of a galvanometer of resistance G ohm is V volt. The resistance required to be connected in series with it, in order to convert it into voltmeter of range nV volt will be........
(1) $\frac{G}{n}$ (2) nG
(3) (n–1)G (4) $\frac{G}{(n-1)}$

8. The scale of a galvanometer of resistance 100Ω contains 25 divisions. It gives a deflection of 1 division on passing a current of 4×10^{-4} A. The resistance in ohm to be added to it, so that it may become a voltmeter of range 2.5 V is.............
(1) 250 (2) 300 (3) 150 (4) 100

9. A galvanometer of resistance 200 Ω gives full scale deflection with 15 milli-ampere current. In order to convert it into a 15V range voltmeter, what is the value of resistance connected in series ?
(1) 1000 Ω (2) 800 Ω
(3) 2500 Ω (4) 1500 Ω

10. A galvanometer, having a resistance of 50 Ω, gives a full scale deflection for a current of 0.05A. The length in metre, of a resistance wire of area of cross-section 2.97×10^{-2} cm^2 that can be used to convert the galvanometer into an ammeter which can read a maximum of 5 A current is
(specific resistance of wire = $5\times10^{-7}\,\Omega$ m)
(1) 1.5 (2) 6 (3) 8 (4) 3

11. An ammeter of range 5A is to be converted into an voltmeter of range 10V. If the resistance of ammeter be 0.1Ω, then what resistance should be connected in series with it ?
(1) 4.9 Ω (2) 2.1 Ω (3) 1.1 Ω (4) 1.9 Ω

12. What is the relation between figure of merit (k) and current sensitivity (S_I) ?

(1) $S_I = k^{-1}$ (2) $S_I = \frac{k}{2}$

(3) $S_I = kV$ (4) $S_I = (k)I$

13. One microammeter has a resistance of 100 Ω and a full scale range of 50 μ A. It can be used as a voltmeter or as a higher range ammeter provided a resistance is added to it. Pick the correct range and resistance combinations (s).

(1) 5 mA range with 2 Ω resistance in parallel

(2) 10 mA range with 1 Ω resistance in parallel

(3) 10 V range with 200 k Ω resistance in series

(4) 50 V range with 10 k Ω resistance in series

14. Current sensitivity of a moving coil galvanometer is 5 div/mA and its voltage sensitivity (angular deflection per unit voltage applied) is 20 div/V. The resistance of the galvanometer is

(1) 40 Ω (2) 25 Ω (3) 250 Ω (4) 500 Ω

15. To know the resistance G of a galvanometer by half deflection method, a battery of emf V_E and resistance R is used to deflect the galvanometer by angle θ. If a shunt of resistance S is needed to get half deflection then G, R and S are related by the equation :

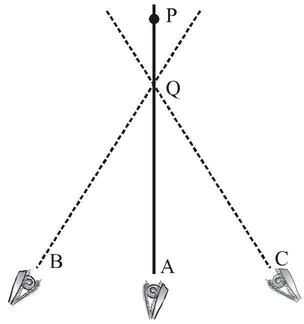
(1) 2S (R+G) = RG (2) S (R+G) = RG

(3) 2G = S (4) 2S = G

ANSWER KEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	1	1	3	3	1	2	3	3	2	4	4	1	3	3	2

FOCAL LENGTH OF CONCAVE MIRROR, CONVEX MIRROR AND CONVEX LENS



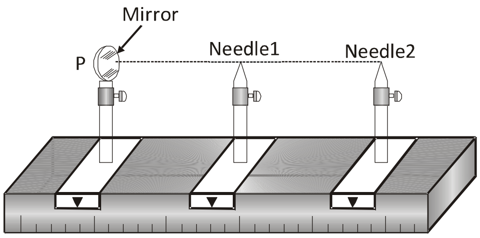
Shows Removal of parallax between P and Q

Parallax : Fix two needles or nails P and Q vertically on a drawing board or on a table. View these pins from position A, so that P appears to be directly behind Q as shown in fig. Now shift your eye to the left, say to position B. You will observe that the more distant needle P appears to move to the left of Q. Similar observation is there when you shift your eye to the right, say to position C.

Thus the object situated at greater distance appears to shift in the same direction as the eye whereas the object situated nearer to the eye, appears to shift in the opposite direction. This apparent shift in the positions of two-objects situated at different distances from the eye, for sideway shift in the position of the eye is called parallax. Parallax may be removed either by moving Q, suitably away from the eye or by moving P towards the eye. When there is no relative shift in the position of P and Q for any position of the eye, then parallax is said to be removed. "No parallax" method or "Removal of parallax" is a very popular method used for tracing or locating the position of the image formed by a mirror or a lens.

Introduction of Optical bench :

An optical bench consists of a horizontal bed made of wood or metal with a meter scale fixed or fitted along its length. There are three (in some cases four) uprights which can slide along the length of the bed. A sketch of a simple optical bench is shown in figure.



[An optical bench]

These uprights carry the optical parts like the mirror (or the lens), the object needle, the image needle (or the screen). These uprights are capable of being given a sideway motion (i.e. perpendicular to the length of the bed) so that the tips of the object and image needle and the centre of mirror (or lens) may be arranged in the same vertical plane. Sharp arrows called the indices are marked on the base of the uprights. These indices help in noting down the positions of the uprights on the scale provided with the bench.

Bench error : The variation between the real distance between the point object and the mirror's pole and the recorded distance calculated on optical bench.

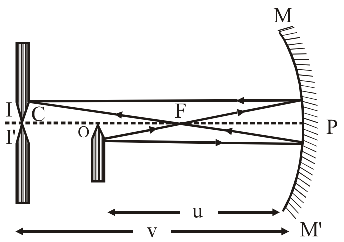
Bench error = Actual distance – Observed distance.

EXPERIMENT-1

Objective : To find the value of **v** for different values of **u** in case of concave mirror and to find the focal length.

Apparatus required : An optical bench along with three uprights, one mirror holder, two needles, given concave mirror etc.

Formula required : Focal length of a mirror $\mathbf{f = \frac{uv}{u+v}}$



where **u** = distance of the object from pole

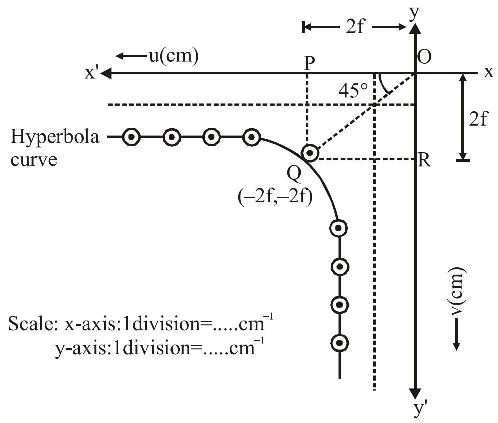
and **v** = distance of the image from pole

Procedure :

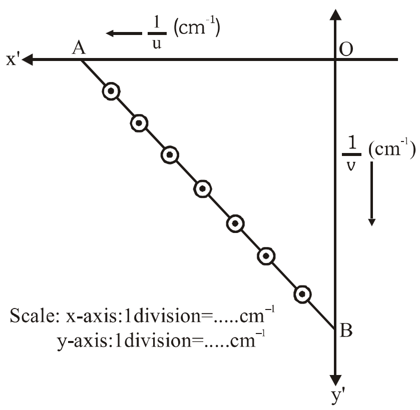
1. Mount the concave mirror in one of the clamp holder such that the principal axis of the mirror is horizontal and parallel to the length of the optical bench.
2. Position the two needles on the uprights and adjust their heights in such a way that the tips of the two needles and the pole of the mirror lie in the same straight line parallel to the length of the optical bench. Mark one pin as object and other image.
3. Bring the object needle towards the pole P of the mirror to a position that lies beyond the focus F but remains between F and C (the centre of curvature of the mirror). Since the object is situated between F and C, so a real and inverted image of the object needle will be formed beyond C as shown. You can see this inverted image in the mirror by closing your one eye and keeping the other eye along the optical bench at the height of the pole of the mirror.
4. Place the second needle on the upright and shift this needle to the position I of the image of the object needle. Remove the parallax between this second needle and the image I of the object needle. In the position of no parallax, the second needle located the position of the image of the object needle.
5. Record the positions of the mirror, the object needle and the image needle on the bench scale and repeat the above steps for five different positions of object needle.

Calculations :

(a)



(b)



In this graph, at point Q

$$u = v = 2f$$

or $OP = OR = 2f$

$\Rightarrow$ $f = \frac{OP}{2}$ or $\frac{OR}{2}$

In this graph, focal length

$$f = \frac{1}{OA} = \frac{1}{OB}$$

Precautions :

1. All the uprights should be vertical.
2. The tip of the needles and pole of mirror should be at same height.
3. Principle axis of the mirror should be horizontal and parallel to the central line of the optical bench.
4. Parallax of the image and object needles should be removed tip to tip.
5. While removing the parallax, the eye should be kept at a minimum distance of 30 cm from the needle.

Sources of error :

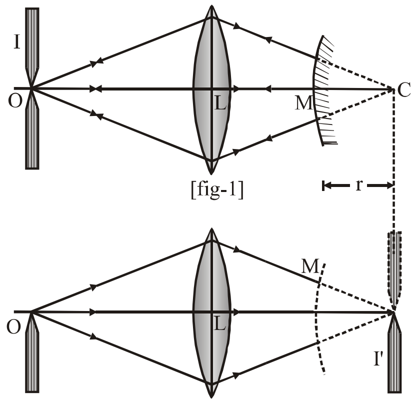
1. The uprights may not be vertical.
2. Parallax removal may not be perfect.

EXPERIMENT-2

Objective : To find the focal length of a convex mirror using a convex lens.

Apparatus required : An optical bench with four uprights, a convex mirror, a convex lens, two needles (an object and an image) etc.

Theory : Suppose a convex lens L is kept between a convex mirror M and an object needle O as shown in figure 1.



[fig-1]

[fig-2]

When the relative positions of M, L and O are adjusted in such a way that there is no parallax between the object needle O and its image I, then in that position, the rays will fall normally on the convex mirror M. The rays which fall on the mirror normally should meet at the centre of curvature C of the mirror when produced as in figure. The distance MC gives the radius of curvature r. Half of the radius of curvature gives the focal length f of the mirror.

Now to get MC, the convex mirror is removed without disturbing the positions of the object O and the lens L and another needle is placed in the position of the image I' of the object O, formed by the lens L as shown in figure 2.. Adjust I' only to remove parallax measure MI'.

The focal length of convex mirror $f = \frac{r}{2} = \frac{MI'}{2}$.

Procedure :

1. Mount the concave mirror M, a convex lens L and the object needle O on an optical bench as shown in figure. Look for the inverted image of O through the lens L and the mirror M by adjusting the position of O or L with respect to that of the mirror. When the inverted image is not obtained, a convex lens of larger focal length should be used.
2. Remove the parallax between the object needle O and its inverted image and note the positions of O, L and M on the bench scale.
3. Remove the mirror M and do not disturb the lens L and O at all. Take another needle I' and place it on the other side of the lens.
   Adjust the position of the needle so that there is no parallax between the needle I' and the inverted image of object needle O formed by the lens. Note this position of the needle I' on the optical bench.
4. Take five sets of observations for different positions of O and L.

Precautions :

1. All the uprights should be vertical.
2. The tip of the needle, pole of the mirror and centre of the lens should be at the same height.
3. Principle axis of the lens should be horizontal and parallel to the central of the optical bench.
4. The convex lens should be placed close to the convex lens.
5. Tip to tip parallax should be removed.
6. While removing the parallax, the eye should be kept at a minimum distance of 30 cm from the needle.

Sources of error :

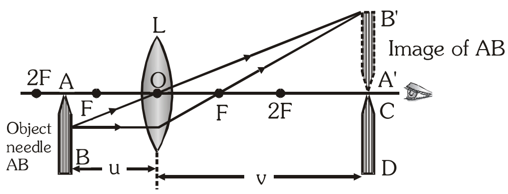
1. The uprights may not be vertical.
2. Parallax removal may not be perfect.
3. Focal length of the lens may not be small.

EXPERIMENT-3

Object : To find the values of v for different values of u in case of a convex lens and to find its focal length.

Apparatus required : An optical bench with three uprights, one lens holder, two needles, given convex lens etc.

Formula required : Focal length of a lens from lens formula $f = \dfrac{uv}{u-v}$.



Ray diagram

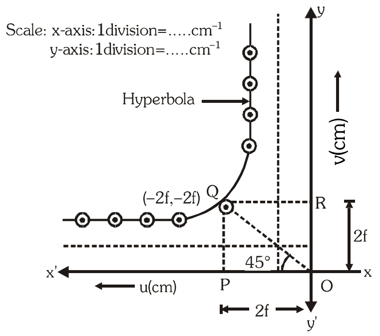
Procedure :

1. Roughly find the focal length of convex lens by focussing a sharp, clear and inverted image of a distant object on a white paper and measuring this distance between the lens and the white paper with a meter scale.

2. Level the optical bench, mount the convex lens on the central upright of the optical bench. On the remaining two uprights mount the two needles. Arrange the tips of the needle at the same vertical height as the centre of the lens.
3. One needle AB is object needle and the other one CD is image needle and to make difference between them tip of one of the needles with a piece of chalk or putting a paper flag on it.
4. Shift the position of the object needle AB to a distance greater than 2f from the lens. Look from the other side of the lens along its principal axis near the end of the bench. If the setting is correct, an inverted, real image A'B' is seen. Now adjust the position of the second needle CD such that parallax between the image of the object needle and the image needle is removed.
5. Note the positions of the lense, the object needle and the image needle on the bench scale and thus find the observed values of u and v.
6. Repeat the above steps for 5 different positions of the object by placing it beyond 2 F and between F and 2F.

CALCULATION FROM GRAPH :

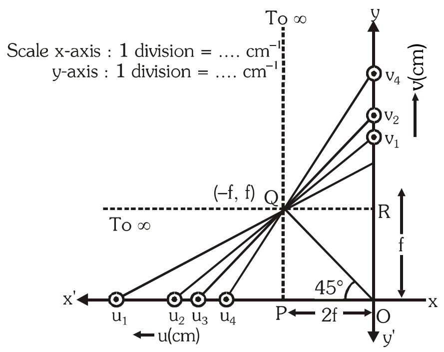
Method-I



In this graph

focal length $f = \frac{QP}{2}$ or $\frac{QR}{2}$

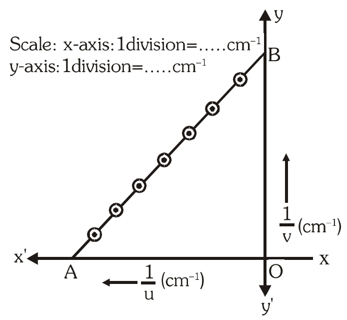
Method-II



In this graph,

focal length f = –QP = QR

Method-III



In this graph,

focal length $f = \frac{1}{OA} = \frac{1}{OB}$

Precautions :

1. All the uprights should be vertical.
2. The tip of the needles and centre of lens should be at same height.
3. Principle axis of the lens should be horizontal and parallel to the central line of the optical bench.
4. Parallax of the image and object needles should be removed tip to tip.
5. The object needle should be placed at such a distance that only real, inverted image of it, is formed.

Sources of Error :

1. The uprights may not be vertical.
2. Parallax removal may not be perfect.

MULTIPLE CHOICE QUESTION

1. Which of the following statement is false -

(1) the bench correction is always equal to the negative of bench error

(2) larger the distance between the two objects larger the magnitude of parallax

(3) parallax disappear if the positions of two objects coincide

(4) parallax can occur between any two objects

2. The focal length of a convex mirror is obtained by using a convex lens. The following observations are recorded during the experiment-

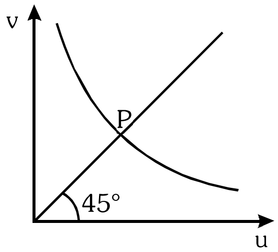
object position	= 5 cm
lens	= 35.4 cm
Image	= 93.8 cm
Mirror	= 63.3 cm
Bench error	= –0.1 cm

then the focal length of mirror will be -

(1) 7.5 (2) 8.4 cm

(3) 15.3 cm (4) none of these

3. A student gets a graph u versus v for a mirror. Point plotted above the point P on the curve are for values of v -



(1) smaller than f (2) smaller than $2f$

(3) larger than 2f (4) larger than f

4. In an optics experiment, with the position of the object fixed, a student varies the position of a convex lens and for each position, the screen is adjusted to get a clear image of the object. A graph between the object distance u and the image distance v, from the lens, is plotted using the same scale for the two axes. A straight line passing through the origin and making an angle of 45° with the x-axis meets the experimental curve at P. The coordinates of P will be –

(1) (2f, 2f) (2) $\left(\frac{f}{2},\frac{f}{2}\right)$

(3) (f, f) (4) (4f, 4f)

5. A plano-convex lens of unknown material and unknown focal length is given. With the help of a spherometer we can measure the

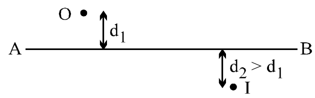
(1) focal length of the lens

(2) radius of curvature of the curved surface

(3) aperture of the lens

(4) refractive index of the material

6. In the figure shown, the image of a real object is formed at point I. AB is the principal axis of the mirror. The mirror must be :



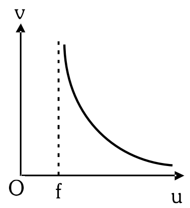
(1) concave & placed towards right I

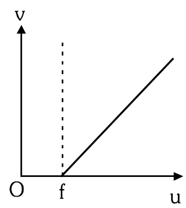
(2) concave & placed towards left of I

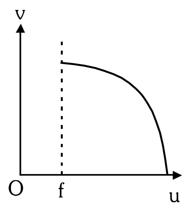
(3) convex and placed towards right of I

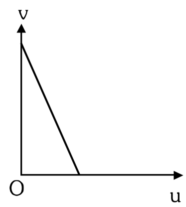
(4) convex & placed towards left of I.

7. Select a graph between 'v' and 'u' for a concave mirror.

(1) 

(2) 

(3) 

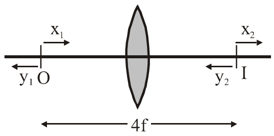
(4) 

8. In the displacement method, a convex lens is placed in between an object and a screen. If the magnification in the two positions are m_1 and m_2,(m_1 > m_2), the distance between the two positions of the lens is x, the focal length of the lens is

(1) $\frac{x}{m_1+m_2}$ (2) $\frac{x}{m_1-m_2}$

(3) $\frac{x}{(m_1+m_2)^2}$ (4) $\frac{x}{(m_1-m_2)^2}$

9. In a converging lens of focal length f and the distance between real object and its real image is $4f$. If the object moves x_1 distance towards lens its image moves x_2 distance away from the lens and when object moves y_1 distance away from the lens its image moves y_2 distance towards the lens, then choose the correct option:-



(A) $x_1 > x_2$ and $y_1 > y_2$

(B) $x_1 < x_2$ and $y_1 < y_2$

(C) $x_1 < x_2$ and $y_1 > y_2$

(D) $x_1 > x_2$ and $y_2 > y_1$

10. What do you mean by term "parallax"?

(1) when reflected ray from mirror are parallel

(2) lateral shift between image of an object viewed from two different positions

(3) when incident & refracted ray are parallel

(4) none of these

11. For practical use, which color we take for the refractive index of a material of lens and glass slab.

(1) red (2) blue

(3) yellow (4) green

12. State the following statements as true or false.

(a) the bench correction is always equal to the negative of bench error

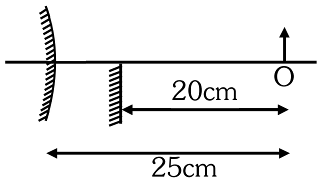
(b) parallax disappear if the position of two objects coincide

(c) parallax can occur between any two object

(1) TFF (2) TTT

(3) FTT (4) FTF

13. An object is placed 25 cm from the surface of a convex mirror and a plane mirror is set so that the image formed by the two mirror lie adjacent to each other is same plane (no parallax). The plane mirror is placed at 20 cm from the object. What is the radius of curvature of convex mirror?



(1) 50 cm (2) 75 cm

(3) 90 cm (4) 60 cm

ANSWER KEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13
Ans.	1	3	3	1	2	2	1	2	3	2	3	3	2

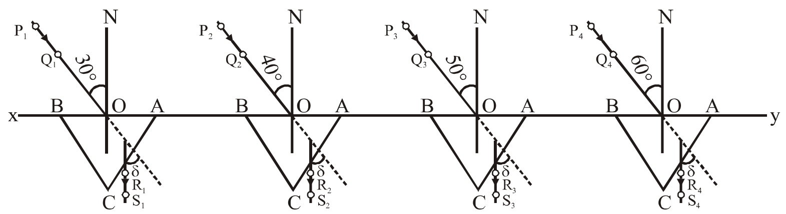
THE PLOT OF THE ANGLE OF DEVIATION VS ANGLE OF INCIDENCE FOR A TRIANGULAR PRISM

Object : To determine angle of minimum deviation for a given glass prism by plotting a graph between the angle of incidence and angle of deviation.

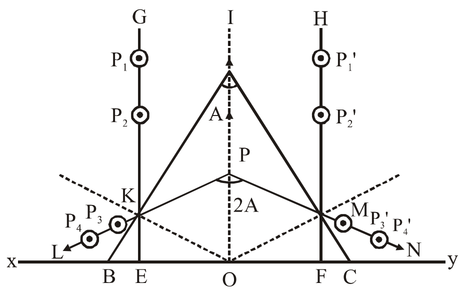
Apparatus : A drawing board, a sheet of paper, triangular glass prism, alpins, a half metre scale, a graph paper and a protector.

Procedure :

1. A white paper sheet is affixed on drawing board. Draw a straight line XY nearly at the centre of the sheet parallel to its length. Mark points, marked as O at suitable spacings on this line XY and draw normals to the line XY at points O as shown in fig. Draw straight line PQ as incident rays that are drawn at angles of incidence 30°, 40°, 50° and 60° using a protractor.
2. Place the prism with one of it refracting surface on the line XY and trace its boundary ABC as shown below.

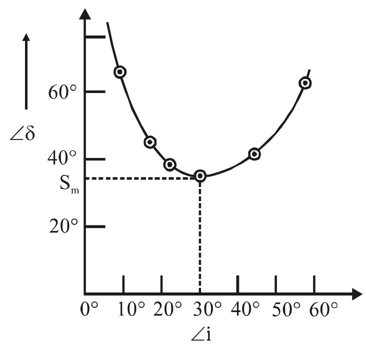


3. Fix two pins P and Q about 8 cm apart on the incident ray line and view its image with one eye closed from the face AC of the prism. Fix two pins R and S on the paper such that the tips of these pins and the tips of the images of the incident ray pins P, Q, R & S and mark with circles their pin pricks.
4. Remove pins P, Q, R & S and mark with circles their pin pricks.
5. Join the points (i.e. pin pricks) S and R and produce it backwards to meet the incident ray PQ produced (shown by dotted lines). Thus RS is the emergent ray corresponding to the incident ray PQ. Draw arrow heads to show the direction of the rays.
6. Measure the angle of deviation δ with a protractor and repeat the procedure for different values of angle of incidence and measure the corresponding angles of deviation δ.
7. To measure angle of refraction 'A' of the prism, mark points O in the middle of XY and E and F on either side of O equidistant from E such that OE = OF (say 1 cm each).



8. Draw three vertical lines EG, OI and FH through E, O and F respectively, such that these are parallel to each other.
9. Place the prism with its refracting edge A on the line OI such that BC is along XY. The points E and F would be symmetric with respect to edges B and C. Draw the boundary ABC of the face of prism touching the board.
10. Fix pins P_1 and P_2 vertically, 4cm apart, observe their reflection in the face AB and fix the pin P_3 such that the images of P_1, P_2 and P_3 are in a straight line. Fix another pin P_4 such that prick of P_4 is also in the same straight line. Join the pricks of P_3 and P_4 by line LK and produce it backward. KL is reflected ray of incident ray GK.
11. Similarly locate NM by joining P_3', P_4' as the reflected ray of incident ray HM. Draw NM backward to meet the line LK produced backward at point P. The point P should lie on the line OI if observations are correctly taken.
12. The angle LPN is equal to $2\angle A$ (it can be proved geometrically from the figure). Measure the angle LPN and determine $\angle A$, (the angle of prism).

Plotting the Graph Between $\angle i$ and $\angle\delta$: Plot a graph between angles i and δ for various sets of values recorded in the observation table. The graph will be a curve as shown in fig.



(Angle of minimum deviation)

Precautions :

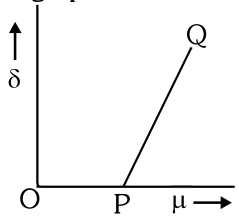
1. The pins should be fixed vertical.
2. A sharp pointed pencil should be used for drawing boundary of the prism and for making pin pricks.
3. The angle of incidence should lie in between 30°–60°.
4. Arrow heads should be marked to represent the incident and emergent rays.

Sources of error :

1. Pin pricks may be thick.
2. Parallax removal may not be perfect.
3. Measurements of angles may be wrong.

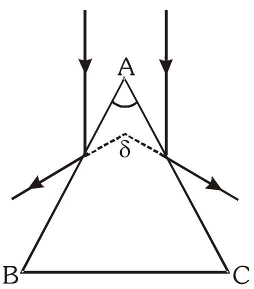
MULTIPLE CHOICE QUESTION

1. In an experiment for a small angled prism, angle of prism A, the angle of minimum deviations (δ) varies with the refractive index of the prism as shown in the graph -



(1) Point P corresponds to μ = 1
(2) Slope of the line PQ = A/2
(3) Slope = 2A
(4) None of the above statements is true

2. A parallel beam of light is incident on a prism as shown in figure, such that the rays get reflected from opposite faces. The angle of deviation δ between reflected rays from faces AB and AC is –



(1) A
(2) 2A
(3) $\frac{A}{2}$
(4) Non relation between A and δ

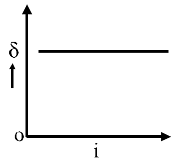
3. A given ray of light suffers minimum deviation in an equilateral prism P. If refractive index increases slightly then the ray will suffer

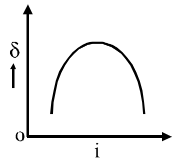
(1) greater deviation
(2) no deviation
(3) same deviation as before
(4) lesser deviation

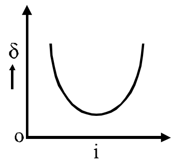
4. When a ray of light is refracted by a prism such that the angle of deviation is minimum, then

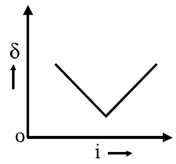
(1) the angle of emergence is equal to the angle of incidence
(2) the angle of emergence is greater than the angle of incidence
(3) the angle of emergence is smaller than the angle of incidence
(4) the sum of the angle of incidence and the angle of emergence is equal to 90°

5. The graph between angle of deviation (δ) and angle of incidence (i) for a triangular prism is represented by :-

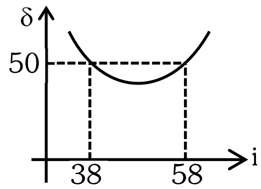
(1) 

(2) 

(3) 

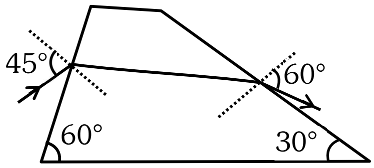
(4) 

6. From the graph, (between δ & i) prism angle is



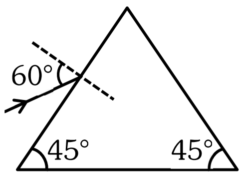
(1) 47° (2) 46° (3) 45° (4) 60°

7. If a ray is passing through a broken prism, find angular deviation for the ray



(1) 105° (2) 30°
(3) 60° (4) 15°

8. A light ray passing through prism is parallel to the base. Refractive index of material is



(1) $\frac{\sqrt{3}}{2}$ (2) $\sqrt{3}$ (3) $\sqrt{2}$ (4) $\sqrt{\frac{3}{2}}$

ANSWER KEY

Que.	1	2	3	4	5	6	7	8
Ans.	**1**	**2**	**1**	**1**	**3**	**2**	**4**	**4**

REFRACTIVE INDEX OF A GLASS SLAB USING A TRAVELLING MICROSCOPE

Travelling Microscope :

It is a compound microscope fitted vertically on a vertical scale. It can be moved up and down. It consist of a vernier scale moving along the main scale.

The reading is taken by combining the main scale and vernier scale reading.

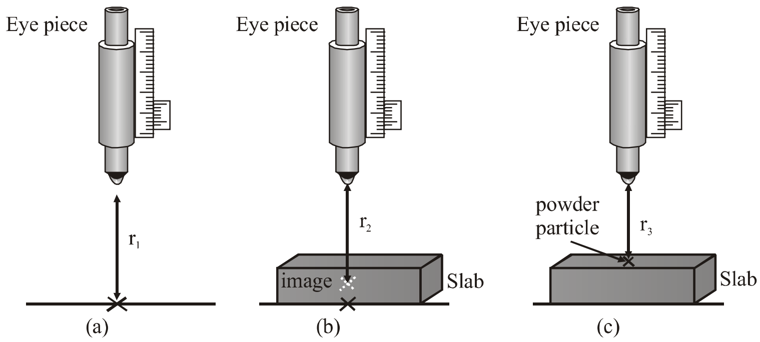
EXPERIMENT

Objective: To determine the refractive index of a glass slab using a travelling microscope.

Apparatus: A marker, glass slab, travelling microscope, lycopodium powder etc.

Theory and principle: For determination of refractive index, by measuring real and apparent depth, a travelling microscope is used.

If the reading microscope when focussed on ink mark on white paper r_1, reading when the slab is kept over the ink mark is r_2 and the reading of image of lycopodium powder then real depth = $r_3 - r_1$ and apparent depth = $r_3 - r_2$. Therefore refractive index of the material of slog $\boxed{\mu = \frac{r_3 - r_1}{r_3 - r_2}}$.



Procedure :

1. Note the number of divisions of vernier which coincide with number of main scale divisions. Find the value of each main division and hence least count of the microscope scale as (1 M.S.D.– V.S.D.).
2. Set the microscope in its stand such that it is capable of sliding vertically up and down as the screw attached to rack and pinion is turned.
3. Mark a cross on a sheet of paper and place it below the objective of the microscope. Move the microscope very gently. Using the screw, focus the eye piece on cross mark and bring the cross in focus such that the cross of cross wires, coincides with the marked cross on the paper. Note the reading of the microscope as r_1.
4. Place the given glass slab on the cross mark. The cross mark appears to be raised.
5. Move the microscope gradually and gently upward to bring the cross mark in focus and on cross of cross wires. Record the reading as r_2.
6. Sprinkle some fine powder on the glass slab and move the microscope upward till the poweder particles come into focus. Record the reading on the scale as r_3.
7. $r_3 - r_1$ = real depth and $r_3 - r_2$ = apparent depth

Precautions :

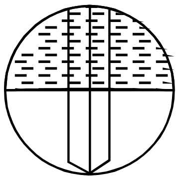
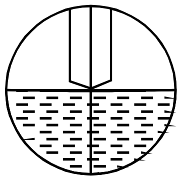
1. Microscope should be focused properly and reading should be taken carefully.
2. Extremely small amount of powder should be used.

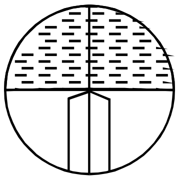
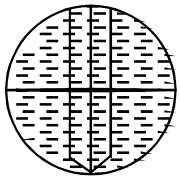
Source of error :

1. Microscope may not be focused well.
2. It may have faulty calibration.

MULTIPLE CHOICE QUESTIONS

1. To measure the height of water level a student sees the pointer tip through the travelling microscope he must have seen this image -

(1)  (2) 

(3)  (4) 

2. An experiment is performed to find the refractive index of glass using a travelling microscope in this experiment distances are measured by -

(1) a standard laboratory scale
(2) a meter scale provided on the microscope
(3) a screw gauge provided on the microscope
(4) a vernier scale provided on the microscope

3. A mark on a table top is seen by a student through a microscope at a distance of 30 cm from the microscope. Seeing along same vertical path, he puts a slab in between microscope and table top at any position. He finds that he is to move the microscope by 5 cm, away from the slab to see the focussed image of the same mark. If refractive index of glass slab is 1.5. The thickness of glass slab introduced is –

(1) 15 cm (2) 5 cm (3) 30 cm (4) 20 cm

4. A student in an experiment gets following observations.
Reading for the bottom of an empty beaker = 12.324 cm.
Reading for the bottom of the beaker when partially filled with the liquid = 12.802 cm.
Reading for the liquid surface = 13.895 cm.
The refractive index would be -

(1) 1.232 (2) 1.389 (3) 1.280 (4) 1.437

5. In an experiment, microscope is focused on a scratch on the bottom of a beaker. Turpentine oil is poured into the beaker to a depth of 4 cm, and it is found necessary to raise the microscope through a vertical distance of 1.28 cm to bring the scratch again into focus. The refractive index of the turpentine oil would be -

(1) 1.28 (2) 1.82 (3) 1.47 (4) 3.12

6. An experiment is performed to find the refractive index of glass using a travelling microscope. In this experiment distances are meausred by

(1) a vernier scale provided on the microscope
(2) a stanard laboratory scale
(3) a meter scale provided on the microscope
(4) a screw gauge provided on the microscope

7. A microscope is focussed on a mark on a piece of paper and then a slab of glass of thickness 3 cm and refractive index 1.5 is placed over the mark. How should the microscope be moved to get the mark in focus again :-

(1) 1 cm upward (2) 4.5 cm downward
(3) 1 cm downward (4) 2 cm upward

8. What is the cause of normal shift(Apparent shift).

(1) reflection of light
(2) refraction of light
(3) Dispersion of light
(4) Total internal refraction

9. On what factor apparent depth depends

(1) Thickness of medium (2) Nature of medium
(3) Color of the light (4) All of these

10. A traveling microscope is focused on a mark on a piece of paper & the scale reading is A. A rectangular block of glass is placed on the paper & the microscope is raised & focused the mark on the paper then microscope reading is B. A layer of lycopodium power is sprinted on the block of glass. The reading now is C. The R.I. of the material of the block is

(1) $\frac{C-B}{C-A}$ (2) $\frac{C-A}{C-B}$ (3) $\frac{C-A}{B-A}$ (4) $\frac{C}{C-A}$

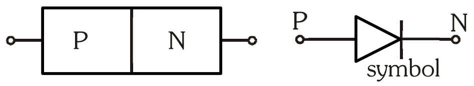
ANSWER KEY

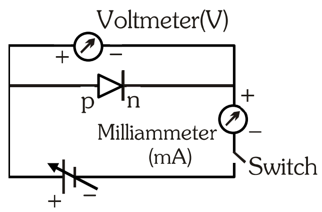
Que.	1	2	3	4	5	6	7	8	9	10
Ans.	3	4	1	4	3	1	1	2	4	2

CHARACTERISTIC CURVES OF A P-N JUNCTION DIODE IN FORWARD AND REVERSE BIAS

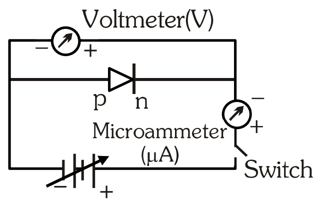
Objective: Characteristic curves of a P-N junction diode in forward bias & reverse bias.

Theory and principle: Characteristic Curve of P-N Junction Diode

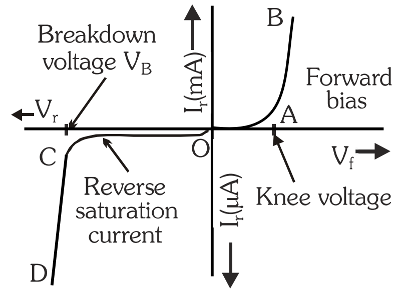




(a) forward bias

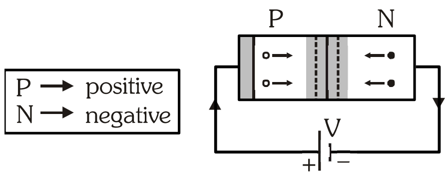
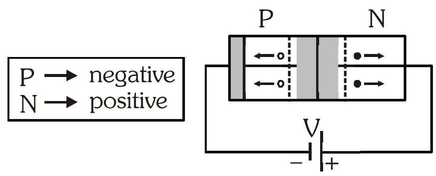
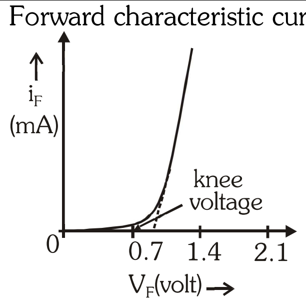
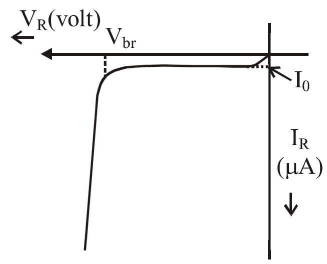


(b) reverse bias



In forward bias, when voltage is increased from 0V in steps and corresponding value of current is measured, the curve comes as OB of figure. We may note that current increases very sharply after a certain voltage knee voltage (cut-in voltage or threshold voltage). At this voltage, barrier potential is completely eliminated and diode offers a low resistance.

In reverse bias a microammeter has been used as current is very very small. When reverse voltage is increased from 0V and corresponding values of current measured the plot comes as OCD. We may note that reverse current is almost constant hence called reverse saturation current. It implies that diode resistance is very high. As reverse voltage reaches value V_B, called breakdown voltage, current increases very sharply, due to Avalanche breakdown.

	Forward Bias		**Reverse Bias**
			
1	Potential Barrier reduces.	1	Potential Barrier increases.
2	Width of depletion layer decreases.	2	Width of depletion layer increases.
3	P-N Junction provides very small resistance.	3	P-N Junction provides high resistance.
4	Forward current flow in circuit.	4	Reverse current flow in circuit.
5	Order of forward current is milliampere.	5	Order of current is micro ampere (Ge) or Nano ampere (Si).
6	Current flows mainly due to majority charge carrier.	6	Current flows mainly due to minority charge carrier.
7	Forward characteristic curve 	7	Reverse characteristic curve 
8	Forward resistance $R_f = \frac{\Delta V_f}{\Delta I_f} \approx 100\,\Omega$	8	Reverse resistance $R_B = \frac{\Delta V_B}{\Delta I_B} \approx 10^6\,\Omega$
9	Knee or cut in voltage Ge $\rightarrow$ 0.3 V , Si $\rightarrow$ 0.7 V	9	Breakdown voltage Ge $\rightarrow$ 25 V, Si $\rightarrow$ 35 V

Precautions : (1) All connections should be clean and tight

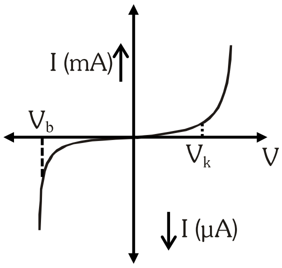
(2) Switch should be used only when the circuit is being used.

(3) Reverse bias voltage beyond breakdown should not be applied.

MULTIPLE CHOICE QUESTIONS

1. The V-I characteristic for a p-n junction diode is plotted as shown in the figure. From the plot we can conclude that

[$V_b \rightarrow$ breakdown voltage, $V_k \rightarrow$ knee voltage]



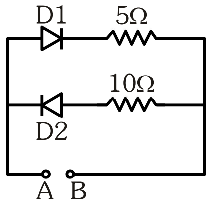
(1) the forward bias resistance of diode is very high; almost infinity for small values of V and after a certain value it becomes very low

(2) the reverse bias resistance of diode is very high in the beginning up to breakdown voltage is not achieved

(3) both forward and reverse bias resistances are same for all voltages

(4) both (1) and (2) are correct

2. A 2V battery is connected across AB as shown in the figure. The value of the current supplied by the battery when in one case battery's positive terminal is connected to A and in other case when positive terminal of battery is connected to B will respectively be :-



(1) 0.1 A and 0.2 A

(2) 0.4 A and 0.2 A

(3) 0.2 A and 0.4 A

(4) 0.2 A and 0.1 A

3. Pick out the incorrect statement:
The reverse current in an ideal p-n junction diode

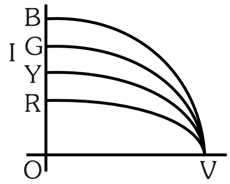
(1) can be minimum and constant before breakdown voltage.

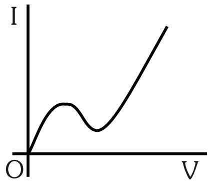
(2) remains constant even after the breakdown voltage.

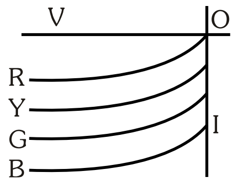
(3) becomes infinity at breakdown.

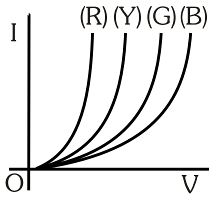
(4) reverse current is controlled by external resistance.

4. The I-V characteristic of an LED is

(1) 

(2) 

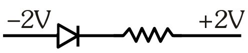
(3) 

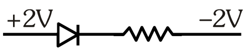
(4) 

5. The forward biased diode connection is:

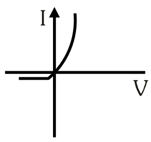
(1) 

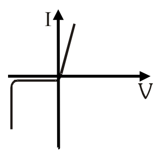
(2) 

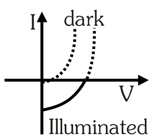
(3) 

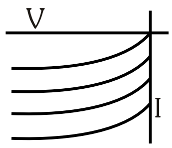
(4) 

6. Identify the semiconductor devices whose characteristics are given below, in the order (a), (b), (c), (d) :-

(a) 

(b) 

(c) 

(d) 

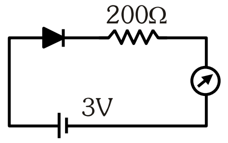
(1) Zener diode, Solar cell, Simple diode, Photodiode

(2) Simple diode, Zener diode, Solar cell, Photodiode

(3) Zener diode, Simple diode, Photodiode, Solar cell

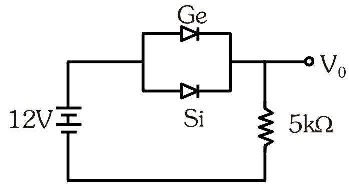
(4) Solar cell, Photodiode, Zener diode, Simple diode

7. The reading of the ammeter for a silicon diode in the given circuit is :-



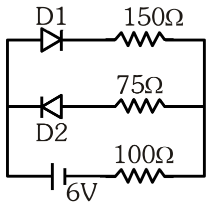
(1) 15 mA (2) 11.5 mA (3) 13.5 mA (4) 0

8. Ge and Si diodes start conducting at 0.3 V and 0.7 V respectively. In the following figure if Ge diode connection are reversed, the value of V_0 changes by : (assume that the Ge diode has large breakdown voltage)



(1) 0.6 V (2) 0.8 V
(3) 0.4 V (4) 0.2 V

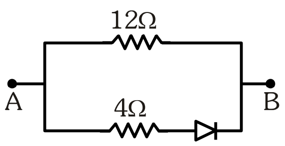
9. The circuit shown below contains two ideal diodes, each with a forward resistance of 50Ω. If the battery voltage is 6 V, the current through the 100 Ω resistance (in Amperes) is :-



(1) 0.027 (2) 0.020
(3) 0.030 (4) 0.036

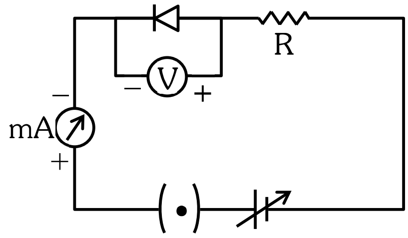
10. In a semiconductor diode, P-side is earthed and N-side is put at potential of –2 V, the diode shall
(1) Conduct (2) Not conduct
(3) Conduct partially (4) Break down

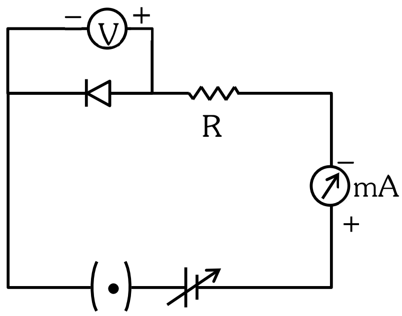
11. Find the equivalent resistance of the network shown in the figure between the points A and B, if (i) $V_A > V_B$ (ii) $V_A < V_B$

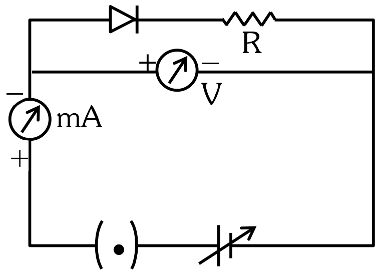


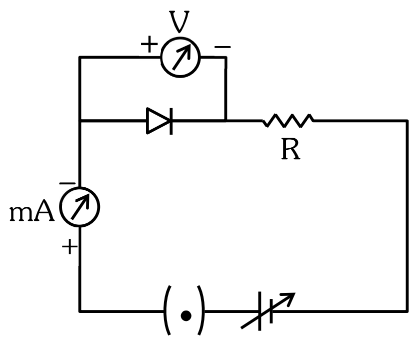
(1) 4Ω, 12Ω (2) 3Ω, 4Ω
(3) 3Ω, 12Ω (4) 12Ω, 3Ω

12. Which one is the correct experimental circuit diagram to draw V.I. characteristic curve for a forward bias PN junction diode.

(1)


(2)


(3)


(4)


13. Which may be the correct possible value of reverse saturation current in a PN junction diode.
(1) 1 μA (2) 500 μA
(3) 1 mA (4) 10 mA

14. Which one is the correct statement :
(1) Diode & Resistor both are ohmic component but diode flows current in one direction.
(2) Diode is non-ohmic but a resistor is an ohmic electrical component and resistor flows current in one-direction.
(3) Diode & resistor both are non-ohmic electrical component and both flows current in one direction.
(4) Diode is non ohmic but resistor is ohmic electrical component, diode flows current in one direction.

15. What occurs after breakdown arises in a real PN junction diode when too much reverse bias voltage applied across it -

(1) Current increases to infinity

(2) Diode gets burnt out

(3) Current reaches to saturation value

(4) Breakdown never occurs

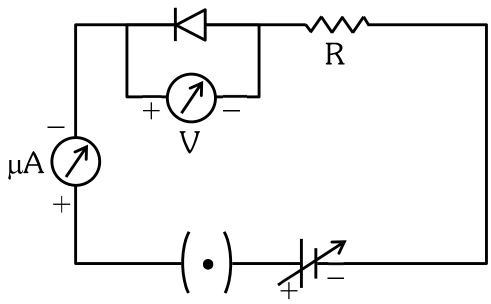
16. During the experiment of forward bias, the least count of voltmeter is 0.5 volt and least count of milliammeter is 0.2 mA. If reading of voltmeter and ammeter is 4 and 40 then values of voltage and current reading through the diode is -

(1) 4V, 60A (2) 2V, 30A

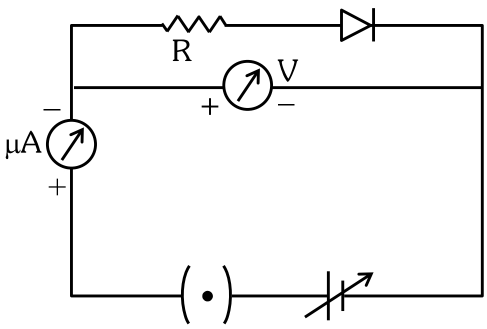
(3) 0.8mV, 30A (4) 2V, 8mA

17. Which one is the correct circuit diagram to draw VI curve for reverse bias PN junction diode characteristic.

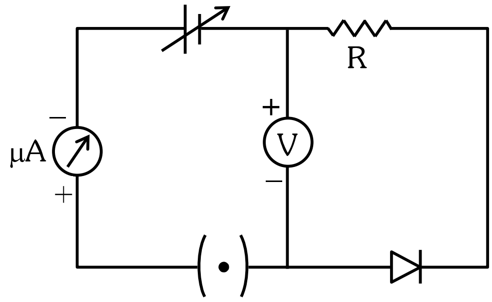
(1)



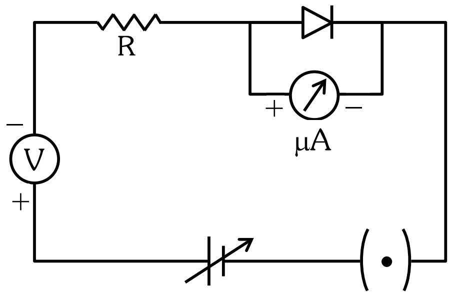
(2)



(3)



(4)

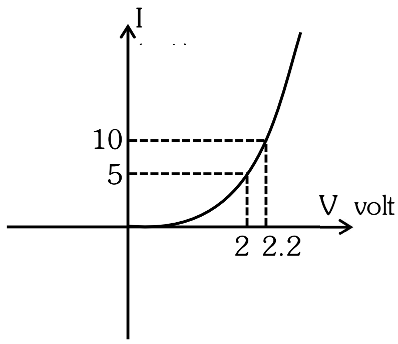


18. The voltage at which forward bias current increases rapidly is called as -

(1) Breakdown voltage (2) Forward voltage

(3) Cut in voltage (4) None of these

19. For the given IV characteristic of P-N junction diode as shown. What is the dynamic resistance of junction diode when 2 volt forward voltage is applied.



(1) 4Ω (2) 40Ω

(3) 400Ω (4) 4000Ω

ANSWER KEY

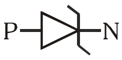
Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	**4**	**2**	**2**	**4**	**4**	**2**	**2**	**3**	**2**	**1**	**3**	**4**	**1**	**4**	**2**
Que.	16	17	18	19											
Ans.	**4**	**1**	**3**	**2**											

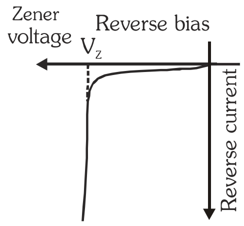
CHARACTERISTIC CURVES OF A ZENER DIODE AND FINDING REVERSE BREAK DOWN VOLTAGE

Objective : Characteristic curve of a zener diode and to determine its reverse breakdown voltage.

Theory and principle:

Zener diode

It is a special purpose diode, designed to operate under the reverse bias in the breakdown region and used in voltage regulation. Symbol of Zener diode is 

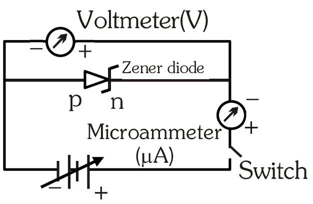


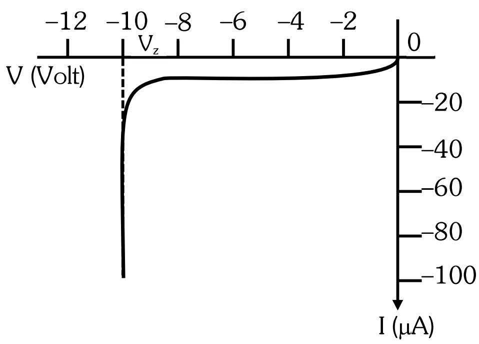
In reverse bias of zener diode after the breakdown voltage V_Z, a large change in the current can be produced by very small change in the reverse bias voltage. In other words zener voltage remains constant, even though current through the zener diode varies over a wide range. This property of the zener diode is used for regulating voltage.

Breakdown are of two types

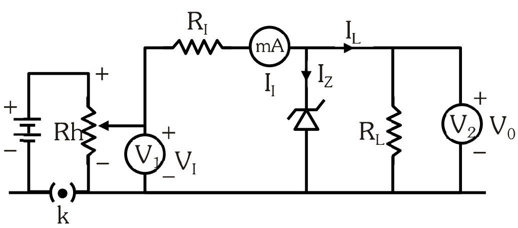
Zener Breakdown	Avalanche Breakdown
• Where covalent bonds of depletion layer, itself break, due to high electric field of Reverse bias voltage. • This phenomena takes place in (i) P – N junction having "High doping" (ii) P – N junction having thin depletion layer • Here P – N junction does not damage permanently. "In D.C voltage stabilizer zener phenomena is used".	• Here covalent bonds of depletion layer are broken by collision of "Minorities" which acquire high kinetic energy from high electric field of very-very high reverse bias voltage. • This phenomena takes place in (i) P – N junction having "Low doping" (ii) P – N junction having thick depletion layer • Here P – N junction damages permanently due to abruptly increment of minorities during repetitive collisions.

The circuit diagram for plotting the characteristics of a Zener diode and determine its reverse breakdown voltage is as shown in the figure below.





Application : Here is a circuit diagram to show the use of zener diode across a load resistance.



Circuit parameters : In the circuit as shown in the figure above.

V_I = Input voltage

V_0 = Output voltage

R_I = Input resistance

R_L = Load resistance

I_I = Input current

I_Z = Zener diode current

I_L = Load current

Relations

$I_L = I_I - I_Z$ ...(i)

$V_0 = V_I - R_I I_I$ ...(ii)

$V_0 = I_L R_L$

Initially as V_I is increased, I_I increases a little, then V_0 increases.

At breakdown, increase of V_I increases I_I by large amount, so that $V_0 = V_I - R_I I_I$ becomes constant.

This constant value of V_0 which is the reverse breakdown voltage is called Zener voltage.

Precautions : (1) All connections should be clean and tight

(2) Switch should be used only when the circuit is being used.

(3) Zero reading of voltmeter and micro ammeter should be checked properly.

MULTIPLE CHOICE QUESTIONS

1. The breakdown in a reverse biased p-n junction diode is more likely to occur due to :-

(i) large velocity of the minority charge carriers if the doping concentration is small

(ii) large velocity of the minority charge carriers if the doping concentration is large

(iii) strong electric field in a depletion region if the doping concentration is small

(iv) strong electric field in the depletion region if the doping concentration is large

(1) (i) and (ii) (2) (ii) and (iii)

(3) (i) and (iii) (4) (i) and (iv)

2. Zener diode is a p-n junction which has -

(1) p-end heavily doped, n-end lightly doped

(2) n-end heavily doped, p-end lightly doped

(3) both p and n-ends heavily doped

(4) both p and n-ends lightly doped

3. Zener diode has both p and n-ends heavily doped so that -

(1) it has small thickness of depletion region

(2) it has large thickness of depletion region due to large recombination

(3) it has large reverse bias voltage

(4) it has weak electric field

4. Most important use of zener diode is to have –

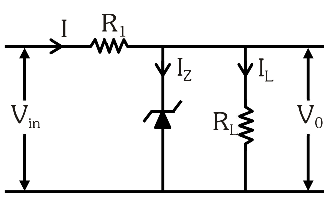
(1) constant voltage across applied load

(2) any desired current at constant voltage

(3) a p-n junction working under constant regulated voltage conditions

(4) a p-n junction to operate at high voltages

5. In given figure when input voltage increases,



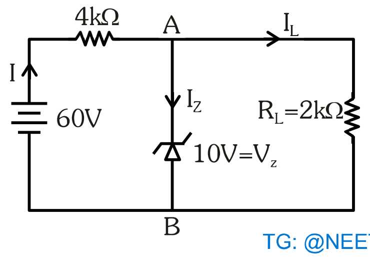
(1) the current through R_S, R_L and zener increases

(2) the current through R_S increases, zener increases but through R_L remains constant

(3) the current through R_S increases, through zener decreases, R_L increases

(4) the current through R_S increases, through zener remains constant but R_L increases

6. A Zener diode is connected to a battery and a load as shown below. The currents I, I_Z and I_L are respectively.



(1) 12.5 mA, 5 mA, 7.5 mA

(2) 15 mA, 7.5 mA, 7.5 mA

(3) 12.5 mA, 7.5 mA, 5 mA

(4) 15 mA, 5 mA, 10 mA

7. Which of the following statements is correct for proper working of zener diode ?

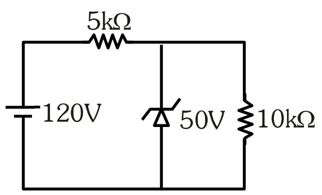
(1) Reverse bias voltage should be less than or equal to zener breakdown voltage

(2) Reverse bias voltage applied must be greater than zener breakdown voltage.

(3) Zener is to be forward biased for zener action

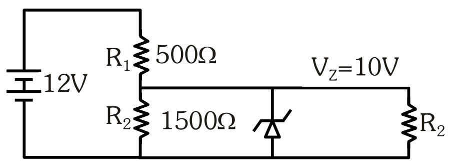
(4) For given zener diode there can be different zener breakdown voltages

8. For the circuit shown below, the current through the Zener diode is :



(1) 5 mA (2) Zero (3) 14 mA (4) 9 mA

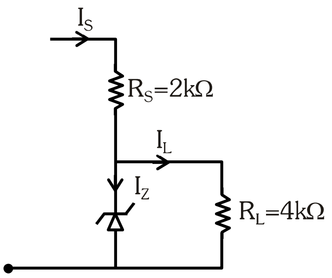
9. In the given circuit the current through Zener Diode is close to :



(1) 6.0 mA (2) 4.0 mA

(3) 6.7 mA (4) 0.0 mA

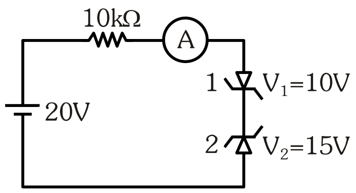
10. Figure shown a DC voltage regulator circuit, with a Zener diode of breakdown voltage = 6V. If the unregulated input voltage varies between 10 V to 16 V, then what is the maximum Zener current ?



(1) 2.5 mA (2) 3.5 mA
(3) 7.5 mA (4) 1.5 mA

11. Zener breakdown occurs in a p-n junction having p and n both :
(1) lightly doped and have wide depletion layer.
(2) heavily doped and have narrow depletion layer.
(3) lightly doped and have narrow depletion layer.
(4) heavily doped and have wide depletion layer.

12. The reading of ammeter in the following circuit.



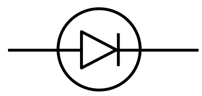
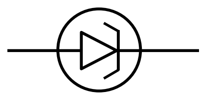
(1) 0.5 mA (2) 1.0 mA
(3) 1.5 mA (4) 2.5 mA

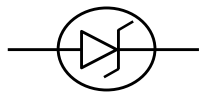
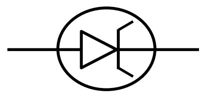
13. Consider the following **statements (A)** and **(B)** and identify the **correct** answer.
(A) A zener diode is connected in reverse bias, when used as a voltage regulator.
(B) The potential barrier of p-n junction lies between 0.1 V to 0.3 V.
(1) **(A)** and **(B)** both are correct.
(2) **(A)** and **(B)** both are incorrect.
(3) **(A)** is correct and **(B)** is incorrect.
(4) **(A)** is incorrect but **(B)** is correct.

14. The incorrect statement about the property of a Zener diode is :-
(1) Zener voltage remains constant at breakdown
(2) It is designed to operate under reverse bias
(3) Depletion region formed is very wide
(4) p and n regions of zener diode are heavily doped

15. Which diode is designed to work under breakdown region ?
(1) Photodiode
(2) Light emitting diode
(3) Solar cell
(4) Zener diode

16. Which is the correct symbol of zener diode ?

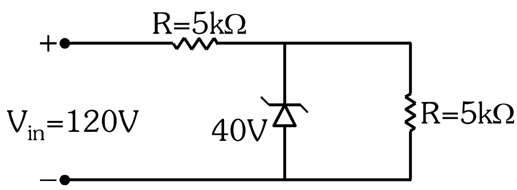
(1)  (2) 

(3)  (4) 

17. A zener is different than PN junction diode due to
(1) Higher doping and higher breakdown voltage
(2) Lower doping and lower breakdown voltage
(3) Higher doping and lower breakdown voltage
(4) Lower doping and higher breakdown voltage

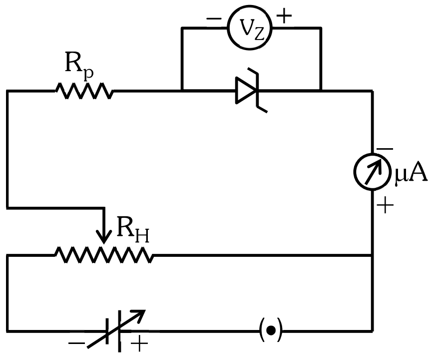
18. What happens during breakdown in zener diode?
(1) Both current and voltage across the zener diode are fixed.
(2) Both current and voltage across the zener diode are varying.
(3) Current increases rapidly but voltage remain constant across it.
(4) Voltage across it is varying but current remain constant.

19. In the circuit, what is the output voltage.



(1) 80 V (2) 40 V
(3) 60 V (4) 120 V

20. A zener diode having zener voltage V_z = 10V and power dissipation rating P_z = 0.4 W. If the diode is in its breakdown condition then what should be the min. protective resistance R_p connected with it in series.



(1) 100 Ω (2) 750 Ω

(3) 250 Ω (4) 125 Ω

ANSWER KEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	**4**	**3**	**1**	**1**	**2**	**3**	**2**	**4**	**4**	**2**	**2**	**1**	**3**	**3**	**4**
Que.	16	17	18	19	20										
Ans.	**3**	**3**	**3**	**2**	**4**										

IDENTIFICATION OF DIODE LED, RESISTOR A CAPACITOR FROM A MIXED COLLECTION OF SUCH ITEMS

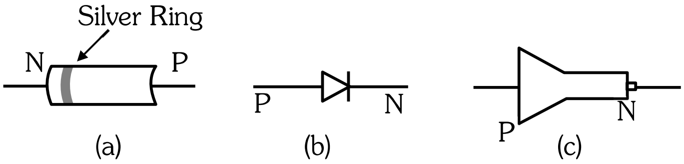
Objective: Identification of Diode. LED, Resistor & a capacitor from a mixed collection of such items.

Theory :

If the component has two terminals, it could be a resistor, a capacitor, a diode or a LED.

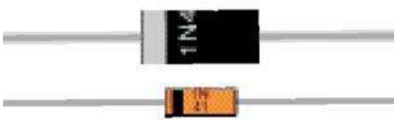
Diode

In some semiconductor junction diodes, a silver ring is shown on one of its end. This end of the diode is n-side and the other end is p-side (Fig. (a)]. In some diodes, the symbol of the diode is painted on the body of the diode. The direction of arrow is the direction of forward bias current flow. Hence, the side from which the arrow starts is p-side and the side towards which the arrow ends is n-side [Fig. (b)). Some diodes are bullet shaped in which case the flat side is p-side and the cylindrical side is n-side [Fig. (c)).



(a) (b) (c)

A diode is a two terminal device. It conducts when forward biased and does not conduct when reverse biased. It does not emit light while conducting.



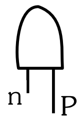
If the multimeter does not show any deflection in one direction and shows deflection with no light emission in the other direction then, the component is a diode.

Light emitting diode

A LED (light emitting diode) is also a two terminal device. It conducts when forward biased and does not conduct when reverse biased. It emits light while conducting.

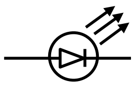
In case of a light emitting diode (LED), usually the shorter pin is n-side and the longer pin is p-side [Fig. (a)].

(a)



(b)

(c)



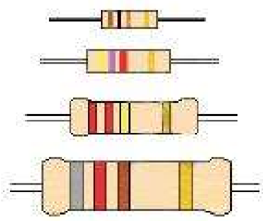
Symbol of LED

If the deflection is accompanied with emission of light, in one direction and a much less or zero deflection in the other direction the component is a LED.

Resistor

A resistor is a two terminal device. It conducts equally in both directions.

Look for colour bands, if it has a typical set of three colour bands followed by a silver or gold band, the component is a resistor.



If the multimeter showns an equal deflection in both the directions, the component is a resistor.

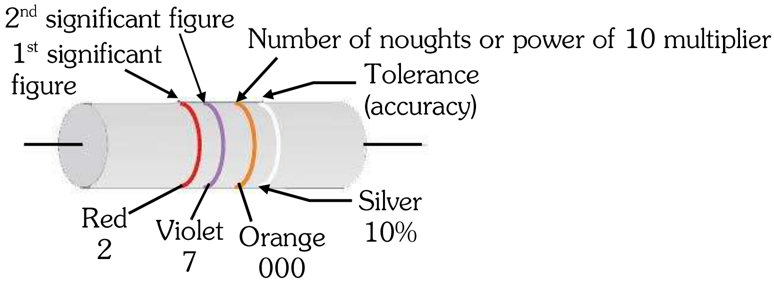
Colour code for resistor

Most common colour code used for resistor consists of three colour bands at one end.

The colour and their numerical meanings are:

Black – 0	Orange – 3	Blue – 6	White – 9
Brown – 1	Yellow – 4	Violet – 7	
Red – 2	Green – 5	Grey – 8	

This colour code could be remembered easily by the term BBROY GB VGW (B B ROY Great Britain Very Good Wife). To read the resistance of a colour coded resistor, start with the strip nearest to the end. The colour of the first strip gives the first digit in the resistance value. The colour of the second strip stands for the second digit. The colour of third strip indicates the value of multiplier or the number of zero following second number.



Resistance for the given resistor

$= 27 \times 10^3 \pm 10\%$ of 27×10^3

$= (27 \pm 2.7) \times 10^3 \Omega$

Resistors with only three bands have a tolerance of 20%. Its actual value may vary 20% up or down from its indicated value. If a fourth band is added separated from the first three, then the tolerance of the resistor is known from the colour of the fourth band. If the colour of the fourth band is silver, then tolerance is 10%. Gold colour represents 5% tolerance red represents 2% and brown represents 1%.

Capacitor

Capacitor is a device that stores electrical charge. A capacitor blocks the passage of dc while it allows ac to flow through it.

There are many types of capacitors having different types of dielectrics in general use. These are

(i) Air capacitor (variable gang capacitors)

(ii) Mica capacitor (low capacitance)

(iii) Ceramic capacitor (very low capacitance)

(iv) Paper capacitor (low capacitance)

(v) Plastic capacitor

(vi) Electrolytic capacitor (medium capacitance)

(vii) Oil filled capacitor (high capacitance)

A capacitor is a two terminal device. It does not conduct but stores some charge when dc voltage is applied. If the multimeter does not show any deflection on connecting its terminals either way to the component, it is a capacitor. But if capacitance of capacitor is large, multimeter may show a momentary deflection.

Summary Table :

	Possible current flow	Device
1.	Unidirectional emits no light	Diode
2.	Unidirectional emits light	LED
3.	Both directions (steady)	Resistor
4.	Initially very high which eventually decays to zero	Capacitor

MULTIPLE CHOICE QUESTIONS

1. For using a multimeter to identify diode from electrical components, choose the correct statement out of the following about the diode :

(1) It is two terminal device which conducts current in both directions.

(2) It is two terminal device which conducts current in one direction only

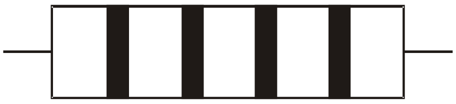
(3) It does not conduct current gives an initial deflection which decays to zero.

(4) None of these

2. A carbon resistor (47 ± 4.7) kΩ is to be marked with rings of different colours for its identification. The colour code sequence will be :-

(1) Violet – Yellow – Orange – Silver
(2) Yellow – Violet – Orange – Silver
(3) Yellow – Green – Violet – Gold
(4) Green – Orange – Violet – Gold

3. The colour code of a resistance is given below

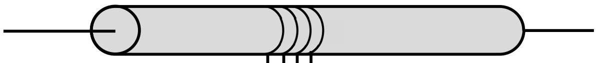


The values of resistance and tolerance, respectively, are :

(1) 470 Ω, 5% (2) 470 kΩ, 5%

(3) 47 kΩ, 10% (4) 4.7 kΩ, 5%

4. The value of resistance for the colour code of the given resistor is:



(1) (470 ± 47) kΩ

(2) (360 ± 36) kΩ

(3) (360 ± 18) kΩ

(4) (36 ± 36) kΩ

ANSWER KEY

Que.	1	2	3	4
Ans.	2	2	1	3

VERNIER CALIPERS-ITS USE TO MEASURE THE INTERNAL AND EXTERNAL DIAMETER AND DEPTH OF A VESSEL

4. As zero of V.S. lies towards right of main scale

$\Rightarrow$ ZE = +ve ; 5^{th} div. of V.S. coincides

$\Rightarrow$ ZE = +5 × 0.1 mm = + 0.5 mm.

5. As zero of V.S. lies toward left of main scale

$\Rightarrow$ ZE = –ve ; 5^{th} div. of V.S. coincides

$\Rightarrow$ ZE = – 5 × 0.1 mm = – 0.5 mm.

6. Least count of vernier is also known as vernier constant

Vernier constant = LC = 1MSD – 1VSD.

7. 1MSD = S units ; 1VSD = V units

$\Rightarrow mV = S(m-1) \Rightarrow mV = Sm - S$

$\Rightarrow V = S - \frac{S}{m} \quad \Rightarrow S - V = \frac{S}{m}$

8. 1MSD = 0.1 cm; 10 VSD = 8 MSD

$\Rightarrow LC = \left(\frac{10-8}{10}\right) \times 0.1 \text{ cm} = 0.02 \text{ cm.}$

9. $1MSD = 1mm; \; LC = \left(\frac{20-19}{20}\right) 1mm = 0.05 \text{ mm}$

ZE = +ve, ZE = +12 × 0.05 mm = +0.60 mm.

10. 1MSD = 0.05 cm, LC = 0.005 cm

a MSD = b VSD

$\Rightarrow \frac{b}{a} = \frac{1MSD}{1VSD} = \frac{0.05}{0.045} = \frac{10}{9}$

11. $1 \text{ MSD} = 1mm ; \; LC = \left(\frac{10-9}{10}\right) 1mm = 0.1mm$

ZE = +ve ; ZE = +8 × 0.1 mm = + 0.8 mm

During measurement : MSR = 41 mm

VSR = 4 × 0.1 mm = 0.4 mm

Corrected reading (CR) :

= 41 mm + 0.4 mm – 0.8 mm

= 40.6 mm = 4.06 cm

12. $LC = \left(\frac{10-9}{10}\right) \times 0.5mm = 0.05 \text{ mm}$

MSR = 78 × 0.5 mm = 39 mm;

VSR = 4 × 0.05 mm = 0.20 mm

Length = 39 mm + 0.20 mm = 39.2 mm

13. $1MSD = \frac{1}{20} \text{ cm} = 0.05 \text{ cm},$

$LC = \left(\frac{10-9}{10}\right) \times 0.05 = 0.005 \text{ cm} = 0.05 \text{ mm}$

ZE = +6 × 0.005cm = + 0.030cm = + 0.30 mm

14. (a) Length data :

MSR = 3.20 cm;

VSR = 8 × 0.005 cm = 0.040 cm

Corrected reading for length :

= 3.20 cm + 0.040 cm – 0.030 cm = 3.210 cm

(b) Diameter data :

MSR = 1.50,

VSR = 6 × 0.005cm = 0.030 cm

Corrected reading for diameter :

= 1.50 cm + 0.030 cm – 0.030 cm = 1.500 cm

15. $LC = \left(\frac{30-29}{30}\right) \times 0.5° = \frac{0.5}{30} \text{degree}$

$= \frac{0.5}{30} \times 60 = 1 \text{ minute}$

16. $N \text{ MSD} = (N + 1) \text{ VSD} \Rightarrow 1VSD = \left(\frac{N}{N+1}\right) MSD$

[Given = 1MSD = a units]

$LC = 1MSD - 1VSD = \left(1 - \frac{N}{(N+1)}\right) a = \left(\frac{1}{N+1}\right) a$

17. 1 MSD = 0.1 cm, LC = 0.02 cm

$\Rightarrow$ 1 VSD = 0.08 cm

$\Rightarrow$ m = n (0.08) $\Rightarrow$ Option (3)

18. $LC = \left(\frac{30-29}{30}\right) \times \frac{1°}{2} = \frac{1°}{60} = 1'$

19. $1MSD = 1mm, \; LC = \left(\frac{10-9}{10}\right) 1mm = 0.1mm$

ZE = +7 × 0.1 mm = + 0.7 mm

MSR = 3.1 cm, VSR = 4 × 0.1 mm = 0.4 mm

Corrected reading of length :

= 3.1 cm + 0.04 cm – 0.07 cm = 3.07 cm

20. MSR = 5.10 cm, 1 MSD = 0.05 cm

$1VSD = \frac{2.45}{50} = 0.049 \text{cm}$

LC = (0.05 – 0.049) cm = 0.001 cm

Reading = 5.10 + (24 × 0.001 cm) = 5.124 cm

21. 1 MSD = 0.1 cm ; LC = 0.01 cm

(1) ZE = -ve ;

ZE = – (10 – 6) × 0.01 cm = – 0.04 cm

(2) Measurement : MSR = 3.1 cm,

VSR = (1 × 0.01 cm) = 0.01 cm

Corrected reading

= 3.1 cm + 0.01 cm – (– 0.04 cm) = 3.15 cm

SCREW GAUGE-ITS USE TO DETERMINE THICKNESS/ DIAMETER OF THIN SHEET/WIRE

2. $LC = \frac{0.1\text{cm}}{200} = 0.005$ mm

3. Distance between consecutive threads = pitch

$LC = 0.005 \text{ mm} = \frac{\text{Pitch}}{100} \Rightarrow \text{Pitch} = 0.5$ mm

4. MSR = 2mm; CSR = 30×0.01 mm = 0.30 mm

Reading = 2mm + 0.30 mm = 2.30 mm

5. $LC = \frac{1\text{mm}}{100} = 0.01$ mm

ZE = +ve; ZE = $+4 \times 0.01$ mm = +0.04 mm

Measurement: MSR = 2 mm

CSR = 57×0.01 mm = 0.57 mm

Corrected reading : (2+0.57–0.04) = 2.53 mm

6. $LC = \frac{1\text{mm}}{50} = 0.02$ mm

ZE = –ve; ZE = $-6 \times 0.02 = -0.12$ mm

Measurement : MSR = 3 mm

CSR : 26×0.02 mm = 0.52 mm

Corrected reading = (3 + 0.52 + 0.12) mm

= 3.64 mm

7. $LC = \frac{0.5\text{mm}}{250} = 0.002$ mm

8. Reading → $(15 \times 0.5 \text{ mm} + 100 \times 0.002 \text{ mm})$

= 7.5 mm + 0.200 mm

= 7.700 mm

9. $LC = \frac{1\text{mm}}{100} = 0.01$ mm

ZE = +13 × 0.01 mm = +0.13 mm

10. MSR = 2 mm

CSR = 73 × 0.01 mm = 0.73 mm

Observed value = (2 + 0.73) = 2.73 mm

11. Acutal thickness = observed value – ZE

= 2.73 mm – 0.13 mm = 2.60 mm

12. $\text{Pitch} = \frac{1\text{mm}}{2} = 0.5$ mm;

$LC = \frac{0.5\text{mm}}{50} = 0.01$mm

ZE = –0.03 mm; MSR = 3 mm;

Corrected reading

= $(3 \text{ mm} + 35 \times 0.01 - (-0.03)) = 3.38$ mm

13. MSR = 0 mm, CSR = 52 div,

$LC = \frac{1}{100} = 0.01$ mm

Diameter = $(0 + 52 \times 0.01)$mm = 0.052 cm

14. $LC = \frac{0.5\text{mm}}{50} = 0.01$ mm;

ZE = –(50–45) × 0.01 mm = –0.05 mm

MSR = 0.5 mm;

CSR = 25×0.01 mm = 0.25 mm

Corrected reading = [0.5 + 0.25 – (–0.05)]

= 0.80 mm

15. ZE = +ve; ZE = + 5×0.005 = + 0.025 mm

Pitch = 200×0.005 mm = 1 mm

During measurement: MSR = 4×1 mm = 4 mm

CSR = 25×0.005 mm = 0.125 mm

Final diameter = (4mm + 0.125mm – 0.025mm)

= 4.100 mm

$\text{Radius} = \frac{4.100}{2} = 2.050$ mm

16. Pitch = 0.5 mm, $LC = \frac{0.5\text{mm}}{50} = 0.01$ mm

ZE = (+5 × 0.01 mm) = + 0.05 mm

During measurement: MSR = 2×0.5 mm=1 mm

CSR = 25×0.01 mm = 0.25 mm

Corrected reading = 1mm+0.25mm – 0.05 mm

= 1.20 mm

18. Pitch = 0.5 mm; $LC = \frac{0.5\text{mm}}{100} = 0.005$ mm

ZE = +ve; ZE = $(+3 \times 0.005)$ = +0.015 mm

During measurement : MSR = 5.5 mm

CSR = 48×0.005 mm = 0.240 mm

Corrected reading = (5.5 + 0.240 – 0.015)

= 5.725 mm

19. $LC = (5 \times 10^{-6}) \times 10^{3} \text{ mm} = \frac{1\text{mm}}{\text{No. of CSD}}$

$\Rightarrow \text{No. of CSD} = \frac{1}{5 \times 10^{-3}} = 200$

20. $LC = \frac{0.1\text{cm}}{50} = 0.002$ cm

Measurement should be be integer multiple of least count

21. LC = 0.01 mm, ℓ = 6.8 cm

Diameter = $(1.5 + 7 \times 0.01)$ = 1.57 mm

= 0.157 cm

SA = $(\pi d\ell)$ = (3.141) (0.157) (6.8) ≃ 3.4 cm^2

22. $LC = \frac{0.5\text{mm}}{50} = 0.01$ mm

Corrected reading = MSR + CSR – ZE

= $[2.5 \text{ mm} + (45 \times 0.01 \text{ mm}) - (-0.03 \text{ mm})]$

= 2.98 mm

SIMPLE PENDULUM-DISSIPATION OF ENERGY BY PLOTTING A GRAPH BETWEEN THE SQUARE OF AMPLITUDE AND TIME

1. Amplitude and energy decrease exponentially.

2. $A = A_0 e^{\frac{-bt}{2m}}$

3. $E = E_0 e^{\frac{-bt}{m}}$

4. $T_{1/2} = 1$ minute

In 3 minutes, $t = 3T_{1/2}$

$\Rightarrow \; A = A_0\left(\frac{1}{2}\right)^3 \Rightarrow A = \frac{A_0}{8} \Rightarrow x = 8$

5. In 2 minutes, $A = \frac{A_0}{3}$

$\Rightarrow$ In 4 minutes, $A = \frac{A_0}{3^2} = \frac{A_0}{9}$

6. $a = a_0 e^{-\alpha t}$

$0.8a_0 = a_0 e^{-50\alpha T} \Rightarrow 1.25 = e^{50\alpha T}$

$a = a_0 e^{-150\alpha T}$

$a = a_0 e^{-150\alpha T} = a_0\left(\frac{0.8a_0}{a_0}\right)^3 = 0.512a_0$

METRE SCALE - THE MASS OF A GIVEN OBJECT BY THE PRINCIPLE OF MOMENTS

1. $m_1r_1 = m_2r_2$

$\frac{r_1}{r_2} = \frac{m_2}{m_1} \Rightarrow r \propto \frac{1}{m}$

2. Centre of mass is towards heavier mass and

$m << M$.

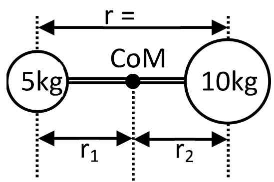
So centre of mass of the system in nearer to M.

3. Let plank shifted by x then $\Delta x_{CM} = 0$, as there is no external force on the system.

$m(L - x_{plank}) - Mx_{plank} = 0$

$x_{plank} = \frac{mL}{M+m}$

4.



About CoM, mr = constant $\Rightarrow r \propto \frac{1}{m}$

$\Rightarrow \frac{r_1}{r_2} = \frac{m_2}{m_1} = \frac{10}{5} = \frac{2}{1}$

$\Rightarrow \; r_1 = \frac{2}{3}r = \frac{2}{3} \times 1 \text{ m} = 67 \text{ cm}$

5. $16\ell_1 \; m\ell_2$ ...(1)

$m\ell_1 = 4\ell_2$ ...(2)

eq. (1) / (2) $\frac{16}{m} = \frac{m}{4}$

$\Rightarrow \; m^2 = 64 \Rightarrow m = 8$ kg

6. $m_1\ell_1 = m_2\ell_2$

$M \times 20 = 40 \times 15$

$M = 30$ g

7. $\tau_R = (300 \times 40) - (500 \times 20) = m_1r_1 - m_2r_2$

$= 2000$ gf. cm

Let 200 gf be suspended at x distance at right hand side.

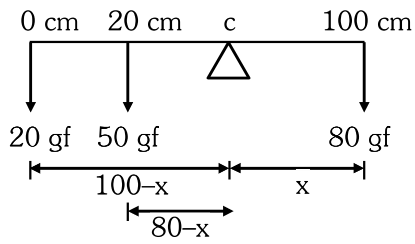
In balanced condition

$\tau_R' = m'_1r'_1 = m_2r'_2 = 0$

$12000 - 10000 - 200x = 0$

$x = 10$ cm

8.



In equilibrium at c

$80x = 20(100 - x) + 50(80 - x)$

$x = 40$ cm

9. In equilibrium

$M \times 30 - W \times 10 = 0$

$3M = W$

$\Rightarrow \frac{W}{M} = 3 > 1$

$\Rightarrow W > M$

10. $(5 \times 50) + W \times 10 = 20 \times 40$

$250 + 10W = 800$

$10W = 550$

$W = \frac{550}{10}$

$W = 55$ gf

YOUNG'S MODULUS OF ELASTICITY OF THE MATERIAL OF A METALLIC WIRE

1. $Y = \frac{F/A}{\Delta\ell/\ell} \Rightarrow \Delta\ell = \frac{F\ell}{YA} = \frac{F\ell}{Y\pi r^2} \Rightarrow \Delta\ell \propto \frac{\ell}{r^2}$

for ℓ = 50 cm & diameter = 0.5 mm,

$\Delta\ell$ is maximum

2. $Y = \frac{\frac{F}{A}}{\frac{\Delta\ell}{\ell}} \Rightarrow \Delta\ell = \frac{F\ell}{AY}$

But $V = A\ell$ so $A = \frac{V}{\ell}$ (V = volume)

Therefore $\Delta\ell = \frac{F\ell^2}{VY} \propto \ell^2$

3. $Y = \Rightarrow \Delta\ell = \frac{F\ell}{AY}$ $(\Delta\ell)_{Steel} = (\Delta\ell)_{Brass}$

$\Rightarrow \frac{W_S\ell}{AY_S} = \frac{W_B\ell}{AY_B} \Rightarrow \frac{W_S}{W_B} = \frac{Y_S}{Y_B} = \frac{2}{1}$

4. $Y = \frac{F\ell}{A\Delta\ell}$ $\because V = A\ell$ so $\ell = \frac{V}{A}$

So $F = \frac{YA\Delta\ell}{\ell} = \frac{YA^2\Delta\ell}{V} \propto A^2$

$\frac{F_1}{F_2} = \left(\frac{A_1}{A_2}\right)^2 \Rightarrow \frac{F}{F_2} = \left(\frac{A}{3A}\right)^2 = \frac{1}{9} \Rightarrow F_2 = 9F$

5. $Y = \frac{\text{stress}}{\text{strain}} = \frac{\text{Stress}}{\text{extension / initial length}}$

$= \frac{4000\times10^3}{2\times10^{-3}/1} = 2\times10^9\ N/m^2$

6. $\frac{\text{Stress}}{\text{Strain}} = y \Rightarrow \frac{F}{A}\frac{\ell}{\Delta\ell} = y$

$\Rightarrow y = \frac{(50\times10)}{10^{-5}} \times \frac{3}{(0.25\times10^{-3})}$

$= 5880\times10^8 \frac{N}{m^2} = 6\times10^{11} \frac{N}{m^2}$

8. $y = \frac{4mgL}{\pi d^2\ell} = 2\times10^{11}$

$\frac{\Delta y}{y} = \frac{\Delta\ell}{\ell} + 2\frac{\Delta d}{d} = \frac{0.05}{0.8} + 2\frac{0.01}{0.4}$

$\Rightarrow \Delta y = 0.225\times10^{11}$

$\Rightarrow y = (2\pm0.2)\times10^{11}\ N/s^2$

9. $\frac{\Delta Y}{Y} = \frac{\Delta\ell}{\ell} + \frac{2\Delta d}{d}$

$\frac{\Delta\ell}{\ell} = \frac{0.005}{0.25} = \frac{1}{50}, \frac{2\Delta d}{d} = \frac{0.005\times2}{0.5} = \frac{1}{50}$

10. $Y = \frac{F/A}{\ell/L} \Rightarrow \frac{\Delta Y}{Y} = \frac{2\Delta d}{d} + \frac{\Delta\ell}{\ell} + \frac{\Delta L}{L}$

$= 2\times\frac{0.001}{0.05} + \frac{0.001}{0.125} + \frac{0.1}{100} = 0.049$

$\Rightarrow \Delta Y = 0.049\ Y$

11. $Y = \frac{\text{Stress}}{\text{Strain}} = \frac{FL}{Al} = \frac{mg.L}{\pi R^2.\ell}$

$\frac{\Delta Y}{Y} = \frac{\Delta m}{m} + \frac{\Delta L}{L} + 2.\frac{\Delta R}{R} + \frac{\Delta\ell}{\ell}$

$\frac{\Delta Y}{Y}\times100 = 100\left[\frac{1}{1000} + \frac{1}{1000} + 2\left(\frac{0.001}{0.2}\right) + \frac{0.001}{0.5}\right]$

$= \frac{1}{10} + \frac{1}{10} + 1 + \frac{1}{5} = \frac{14}{10} = 1.4\%$

12. $y = \frac{MgL^3}{4bd^3\delta}$

$\frac{\Delta y}{y} = \frac{\Delta M}{M} + \frac{3\Delta L}{L} + \frac{\Delta b}{b} + \frac{3\Delta d}{d} + \frac{\Delta\delta}{\delta}$

$\frac{\Delta y}{y} = \frac{10^{-3}}{2} + \frac{3\times10^{-3}}{1} + \frac{10^{-2}}{4} + \frac{3\times10^{-2}}{4} + \frac{10^{-2}}{5}$

$= 10^{-3}\left[0.5 + 3 + 2.5 + 7.5 + 2\right] = 0.0155$

13. L = 1m

$\Delta L = 0.4\times10^{-3}$ m $\Rightarrow$ m = 1kg

$d = 0.4\times10^{-3}$m $\Rightarrow \frac{F}{A} = Y\frac{\Delta L}{L}$

$Y = \frac{FL}{A\Delta L} = \frac{(mg).(1)}{\left(\frac{\pi d^2}{4}\right)0.4\times10^{-3}}$

$\Rightarrow \frac{10\times4}{\pi\left(0.4\times10^{-3}\right)^2\times0.4\times10^{-3}}$

$Y = \frac{40}{\pi\left(0.4\times10^{-3}\right)^3} \Rightarrow Y = \frac{40\times7}{22\times64\times10^{-3}\times10^{-9}}$

$Y = 0.199\times10^{-12}\ N/m^2$

$\frac{\Delta Y}{Y} = \frac{\Delta(\Delta L)}{\Delta(\Delta L)} + \frac{2\Delta d}{d} = \frac{0.02}{0.4} + 2\frac{\Delta d}{d}$

$= \frac{0.2}{4} + 2\times\frac{0.01}{0.4} = \frac{0.1}{2} + \frac{0.1}{2} = 0.1$

$\Rightarrow \Delta Y = 0.1\times Y = 0.199\times10^{11} = 1.99\times10^{10}$

14. $\text{Slope} = \frac{\Delta l/w}{L} = \frac{\Delta l/L}{w} = \frac{1}{YA} \Rightarrow Y = \frac{1}{(\text{slope})A}$

$Y = \frac{1}{2\times10^{-6}(0.25\times10^{-5})} = 2\times10^{11} N/m^2$

15. Stress same

Maximum stress remains same.

16. $V = \pi r^2\ell \Rightarrow \frac{\Delta V}{V} = 2\frac{\Delta r}{r} + \frac{\Delta\ell}{\ell}$

$\frac{\Delta\ell}{\ell} = 0.2\% - 2\times0.002\% = 0.2\% - 0.004\% = 0.196\%$

$\text{stress} = Y\frac{\Delta\ell}{\ell} = 2\times10^{11}\times0.196\times10^{-2} = 0.392\times10^9$

17. Young's modulus of elasticity is independent from length and radius of wire.

18. $W = \frac{1}{2} F \Delta\ell = \frac{1}{2}(5\times10)\times(30\times10^{-2}) = 7.5\text{ J}$

19. $Y = \frac{\text{Stress}}{\text{Strain}}$

max. strain $= \frac{\text{max.stress}}{Y} = \frac{mg/A}{Y}$

$m = \frac{Y \times \text{max.strain} \times A}{g}$

$= \frac{2\times10^{11}\times10^{-3}\times3\times10^{-6}}{10} = 60\text{ kg}$

20. $Y = \frac{\text{Stress}}{\text{Strain}}$

if strain $=1$

then Y = stress

21. $d = 0.5\text{ mm}, Y = 2\times10^{11}, L = 1\text{ m}$

$\because \Delta\ell = \frac{FL}{AY} = \frac{1.2\times10\times l}{\frac{\pi}{4}\times(5\times10^{-4})^2}\times2\times10^{11}$

$\Rightarrow \Delta\ell = \frac{12\times4}{3.2\times25\times10^{-8}}\times2\times10^{11}$

$\Delta\ell = 0.3\text{ mm}$

so 3rd division of VS will coincide with main scale.

22. As $Y = \frac{FL}{A\Delta L}$, when $T\uparrow, \Delta L\uparrow \Rightarrow Y\downarrow$

23. $\Delta\ell = \frac{F\ell}{AL} = \frac{4\times8000\times10\times2.5}{\pi(0.25)^2\times2\times10^{11}} = 0.021\text{ mm}$

SURFACE TENSION OF WATER BY CAPILLARY RISE AND EFFECT OF DETERGENTS

1. Spherical shape of rain-drop is due to surface tension which tries to minimize the surface area.

2. Surface tension of liquid lead, which tries to minimize the surface area and gives a spherical shape.

3. Detergent decreases the oil-water surface tension and helps in removing dirty greasy stains.

4. Elastic membrane is formed on the surface of water due to surface tension. This help's spider & insects to move and run on the surface of water.

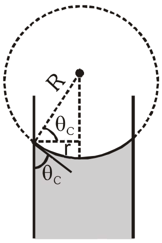
5. For hemispherical meniscus

$R = r$

i.e. $\cos\theta = 1$

$\theta = 0°$

as $R\cos\theta = r$ in capillary tube



$R = \frac{r}{\cos\theta}$

6. A liquid does not wet the sides of a solid, for obtuse (more than 90°) angle of contact.

7. By using water proofing agent like (wax), angle of contact changes from acute to obtuse.

8. $h_1r_1 = h_2r_2$ (Zurin's law)

$\frac{r_1}{r_2} = \frac{h_2}{h_1}$

$\frac{r_1}{r_2} = \frac{66}{22} = \frac{3}{1}$

9. $\because h = \frac{2T\cos\theta}{r\rho g}$

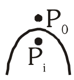
$\therefore h \propto \frac{1}{r} \Rightarrow \frac{h_2}{h_1} = \frac{r_1}{r_2} \Rightarrow h_2 = 2h_1$

Mass of water = $V \times \rho_{water}$

$\therefore \frac{M'}{M} = \frac{\pi\left(\frac{r}{2}\right)^2\times2h\times\rho_w}{\pi r^2\times h\times\rho_w} = \frac{1}{2}$

$\therefore M' = M/2$

10. Meniscus will be convex



$P_i > P_0$

11. Inside a satellite, water will rise upto the top level but will not overflow. Radius of meniscus (R') increases in such a way that final height h' is reduced.

12. $\because h = \frac{2T}{r\rho g} \Rightarrow h \propto \frac{1}{g} \Rightarrow$ at moon $g' = \frac{g}{6}$

So, $h' = 6h$

13. $\because h = \frac{2T\cos\theta}{r\rho g}$

$\therefore h \propto \frac{T}{\rho} \Rightarrow \frac{h_1}{h_2} = \frac{T_1\rho_2}{T_2\rho_1} = \frac{240}{300}\times\frac{0.6}{1.6} = \frac{3}{10}$

14. On liquid force due to surface tension $= (2\pi r)T\cos\theta_C$

In equilibrium : force due to S.T = weight of liquid rise $(2\pi r)T\cos\theta_C = mg$

$$T = \frac{\text{Weight}}{2\pi r} = \frac{6.2}{2\times3.14\times0.2\times10^{-2}} = 500 \text{ N/m}$$

15. At equilibrium : force due to S.T = weight of liquid rise

$(2\pi r)T\cos\theta_C = mg$

$\therefore\ 2\pi r.T = \text{weight} \Rightarrow 2\pi r = \frac{\text{weight}}{T}$

$= \frac{75\times10^{-4}}{6\times10^{-2}} = 12.5 \times 10^{-2}$ m

16. $h = \frac{2T\cos\theta}{r\rho g} = \frac{2\times70\times1}{\frac{1}{14}\times1\times980} = 2$ cm

17. $\ell\cos30^\circ = 4 \Rightarrow \ell = \frac{4}{\cos30^\circ} = \frac{4\times2}{\sqrt{3}} = \frac{8}{\sqrt{3}}$ cm

18. The wettability of a surface by a liquid depends primarily on angle of contact between the surface and the liquid.

(I) acute – wet

(II) obtuse – not wet

19. Water will rise upto the top level but will not overflow. Radius of curvature (R') increases in such a way that final height h' is reduced and given by $h' = \frac{hR}{R'}$ (It is in accordance with Zurin's law)

20. $h = \frac{2T\cos\theta}{\rho g r}$

As r, h, T are same, $\frac{\cos\theta}{\rho} = \text{constant}$

$\therefore\ \frac{\cos\theta_1}{\rho_1} = \frac{\cos\theta_2}{\rho_2} = \frac{\cos\theta_3}{\rho_3}$

As $\rho_1 > \rho_2 > \rho_3$

$\therefore\ \cos\theta_1 > \cos\theta_2 > \cos\theta_3 \Rightarrow \theta_1 < \theta_2 < \theta_3$

As water rises so θ must be acute

So, $0 \le \theta_1 < \theta_2 < \theta_3 < \pi/2$

26. $h \propto \frac{1}{r}$

30. $\Delta P = \frac{2T}{R}$ & $R = \frac{r}{\cos\theta} \Rightarrow \Delta P = \frac{2T}{r}\cos\theta$

31. $T = \frac{rhg}{2}\times10^3$

$$\frac{\Delta T}{T} = \frac{\Delta r}{r} + \frac{\Delta h}{h} + 0$$

$$100\times\frac{\Delta T}{T} = \left(\frac{0.01}{1.25\times10^{-2}} + \frac{0.01}{1.45\times10^{-2}}\right)100$$

= (0.8 + 0.689)

= (1.489)

$100\times\frac{\Delta T}{T} = 1.489\ \%$

= 1.5%

32. Area of tube = πr^2

$$\Rightarrow \frac{A_2}{A_1} = \left(\frac{r_2}{r_1}\right)^2 \Rightarrow \left(\frac{r_2}{r_1}\right) = \left(\frac{A}{4A}\right)^{\frac{1}{2}} = \frac{1}{2}$$

$h \propto \frac{1}{r} \Rightarrow \frac{h_2}{10\text{cm}} = \frac{r_1}{r_2} = 2$

$\Rightarrow h_2 = 20$ cm

33. $hR = h\frac{r}{\cos\theta} = \text{constant}$

$\Rightarrow \frac{h}{\cos\theta} = \text{constant}$

$\frac{2}{\cos0^\circ} = \frac{1}{\cos\theta} \Rightarrow \cos\theta = \frac{1}{2} \Rightarrow \theta = 60^\circ$

CO-EFFICIENT OF VISCOSITY OF A GIVEN VISCOUS LIQUID BY MEASURING TERMINAL VELOCITY OF A GIVEN SPHERICAL BODY

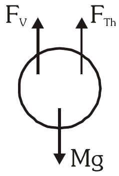
1. The velocity of falling rain drop attain limiting value because viscous force exerted by air.

2. Poise is the unit of viscosity.

3. $F_V = Mg - F_{Th}$

$= Mg\left(1 - \frac{F_{Th}}{Mg}\right)$

$= Mg\left(1 - \frac{D_2}{D_1}\right)$



4. $F_V = 6\,\pi\eta r v_T$

For same fluid and terminal velocity

$F_V \propto r \Rightarrow \frac{F_{V_1}}{F_{V_2}} = \frac{1}{4}$

5. Final velocity is terminal velocity which is independent from 'h'

$v_T = \frac{2r^2}{9}\frac{(\rho - \sigma)}{\eta}g$

6. $v_T \propto r^2 \therefore \frac{v_T'}{v_T} = \left(\frac{R}{r}\right)^2$ or $v_T' = \left(\frac{R}{r}\right)^2 v_T$ ....(1)

when 2 droplets of radius r coalesce to form a big drop of radius R, then -

$\frac{4}{3}\pi R^3 = 2 \times \frac{4}{3}\pi r^3 \Rightarrow \frac{R}{r} = 2^{1/3}$ ....(2)

from equation (1) and (2) -

$v'_T = (2^{1/3})^2 \times 1 = 4^{1/3}$ cm/sec.

7. $v_T \propto r^2$ $\quad \therefore \frac{v_{T_2}}{v_{T_1}} = \frac{r_2^2}{r_1^2}$

$\therefore v_{T_2} = v_{T_1}\left(\frac{r_2}{r_1}\right)^2 = 40 \times \left(\frac{2}{4}\right)^2 = 10$ cm/s.

8. $v_T \propto r^2 \Rightarrow \frac{v_{T_1}}{v_{T_2}} = \left(\frac{r_1}{r_2}\right)^2 = \left(\frac{3}{2}\right)^2 = 9:4$

9. $v_T \propto R^2$ and $M \propto R^3 \Rightarrow v_T^2 \propto \frac{M^2}{R^2}$

10. $\because v_T = \frac{2}{9}r^2\frac{(\rho_w - \rho_{air})g}{\eta}$

$\because \rho_{air} \approx 0$

$\therefore v_T = \frac{2}{9} \times \frac{(1.50 \times 10^{-6})^2 \times 10^3 \times 10}{2 \times 10^{-5}}$

$= 2.5 \times 10^{-4}$ m/s

11. $\because v_T \propto r^2 \Rightarrow \frac{r_1^2}{r_2^2} = \frac{v_{T_1}}{v_{T_2}} = \frac{9}{4} \Rightarrow \frac{r_1}{r_2} = \frac{3}{2}$

$\therefore \frac{V_1}{V_2} = \left(\frac{r_1}{r_2}\right)^3 = \frac{27}{8}$

12. Viscosity of liquid decreases with increase in temperature.

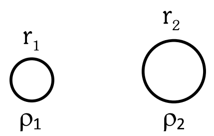
13. Rate of heat produced

$\frac{dQ}{dt} = F_v \times v_T$

$= 6\pi\eta r v_T \times v_T$

$\therefore \frac{dQ}{dt} \propto r v_T^2 \propto r^5 \left(\text{as } v_T = \frac{2r^2}{9\eta}(\rho - \sigma)g\right)$

14.



$v_T = \frac{2r^2(\sigma - \rho)g}{9\eta}$

$\frac{v_1}{v_2} = \left(\frac{r_1}{r_2}\right)^2 \frac{(\sigma_1 - \rho)}{(\sigma_2 - \rho)}$

$= \left(\frac{1}{2}\right)^2\left(\frac{8\rho_2 - 0.1\rho_2}{\rho_2 - 0.1\rho_2}\right) = \frac{79}{36}$

15. Mass = M

Density of ball = d

Density of glycerine = $\frac{d}{2}$

$F_B = V_s \rho_\ell g = V\frac{d}{2}g$

$F_g = Mg = vdg$

for constant velocity, $F_{net} = 0$

$\therefore F_B + F_V = M_g$

$F_V = M_g - F_B = Vdg - \frac{Vdg}{2} = \frac{Vdg}{2} = \frac{Mg}{2}$

17. Viscosity of liquid decreases with increase of temp.

18. $F = 6\,\pi\,\eta\,r\,v$

$= 6 \times 3.14 \times 0.9 \times 5 \times 10^{-3} \times 10 \times 10^{-2}$

$= 847.8 \times 10^{-5}$ N

$= 8.48 \times 10^{-3}$ N

19. $v_T = \frac{2r^2}{9}\frac{(\rho-\sigma)}{\eta}g$

For same size and same liquid

$v_T \propto \rho_b - \rho_\ell$

$\therefore \frac{(v_T)_{silver}}{(v_T)_{gold}} = \frac{\rho_{silver} - \rho_{liq}}{\rho_{gold} - \rho_{liq}}$

$\therefore (v_T)_{silver} = \left(\frac{10.5-1.5}{19.5-1.5}\right)\times 0.8 = 0.4 \text{ m/s}$

20. $\because p = mv \Rightarrow p \propto r^5 \Rightarrow \frac{p_1}{p_2} = \frac{1}{32}$

21. for liquids

T↑, η↓

and for surface tension

T↑, ST↓

22. $v_T = \frac{2}{9}\frac{r^2(\rho_B - \rho_L)g}{\eta}$

$v_T \propto \frac{r^2 g}{\eta}$

but $m \propto r^3 \Rightarrow \frac{m}{r} \propto r^2 \Rightarrow v_T \propto \frac{mg}{\eta r}$

23. $v_T \propto (\rho_B - \rho_L)$

$\frac{(v_T)_{marble}}{(v_T)_{brass}} = \frac{(\rho_m - \rho_L)}{(\rho_B - \rho_L)} = \frac{(2.5-0.8)}{(8.5-0.8)}$

$= \frac{1.7}{7.7} = \frac{17}{77}$

24. $v_T = \frac{2}{9}\frac{r^2(\rho_B - \rho_L)g}{\eta}$

Here velocity are same

$r^2 \propto \frac{1}{\rho_B - \rho_L}$

$\frac{r_A}{r_B} = \sqrt{\frac{(11\times 10^3)-(2\times 10^3)}{(8\times 10^3)-(2\times 10^3)}} = \sqrt{\frac{9}{6}} = \sqrt{\frac{3}{2}}$

SPEED OF SOUND IN AIR AT ROOM TEMPERATURE USING A RESONANCE TUBE

1. The wavelength of sound produced in the pipe is

$$\lambda = \frac{v}{f} = \frac{332}{512} = 0.648 \text{ m} = 64.8 \text{ cm}$$

the wavelength of fundamental note produced by the pipe is

$$\lambda_0 = 4\ell = 180 \text{ cm}$$

Since $\lambda_0 >> \lambda$, therefore it is not sounding in fundamental mode

The wavelength of the first overtone is

$$\lambda_1 = \frac{4\ell}{3} = 60\text{cm}$$

Since λ_1 is closer to 64.8 cm, therefore by allowing the effect of end-correction it is vibrating in first overtone.

2. $\ell + e = \frac{3\lambda_1}{4} = \frac{3v}{4f}$

$$e = \frac{3v}{4f} - \ell = 3.6 \text{ cm}$$

3. $D = \frac{e}{0.3} = 12\text{cm}$

Frequency of tuning fork	Position of water level at resonance L_2(cm)				Mean length of air column L_2–L_1 (cm)
	Resonance	Water falling	Water rising	Mean L_2	
480	First	17.0	17.2	17.1	$\ell_1 = 16.9$
	Second	52.4	52.6	52.5	$\ell_2 = 52.3$
512	First	16.4	16.2	16.3	$\ell_1' = 16.1$
	Second	49.9	50.1	50.0	$\ell_2' = 49.8$

(Table content from question)

4. $v_1 = 2f_1 (\ell_2 - \ell_1)$

$= 2(480)\ (0.523 - 0.169)\text{m} = 340 \text{ m/s}$

$v_2 = 2f_2 (\ell_2 - \ell_1) = 345 \text{ m/s}$

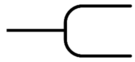
$$v = \frac{v_1 + v_2}{2} = 342.5 \text{ m/s}$$

5. $e_1 = \frac{\ell_2 - 3\ell_1}{2} = 0.8\text{cm}$

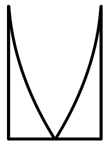
$$e_2 = \frac{\ell'_2 - 3\ell'_1}{2} = 0.75\text{cm}$$

$$e = \frac{e_1 + e_2}{2} = 0.77\text{cm}$$

6. For closed pipe



$$n = \frac{v}{4\ell} = 512$$



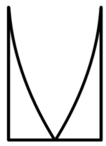
For open pipe

$$n = \frac{v}{2\ell} = 1024$$

n = 1024 Hz.

7. $n = \frac{v}{4\ell}$

n = 264 Hz



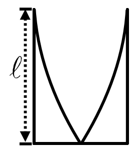
v = 330 m/s

Then

ℓ = 31.25 cm

8. Fundamental frequency

$$n = \frac{v}{4\ell}$$



v = 320 m/s

ℓ = 1 m., n = 80 Hz

For closed pipe

$n_1 : n_2 : n_3$ = ... = 1 : 3 : 5 : ....

frequency 80, 240, 400, ...

9. $L = (2n-1)\frac{\lambda}{4}$

$$= \frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4}, \ldots\ldots\ldots\ldots$$

10. $L = (2n-1)\frac{\lambda}{4}$

$\ell_1 = \frac{\lambda}{4}$ ____(i)

$\ell_2 = \frac{3\lambda}{4}$ ____(ii)

distance of displacement antinode from top.

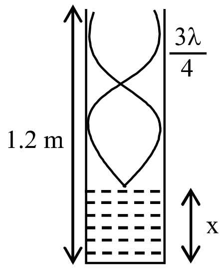
$$\frac{\ell_2 - 3\ell_1}{2}$$

11. $v = f\lambda$

$\lambda = \frac{340}{340} = 1m$

$x = 1.2 - \frac{3\lambda}{4} = 1.2 - 0.75$

$x = 0.45$ m = 45 cm



12. $\ell_2 - \ell_1 = \frac{\lambda}{2}$

$51 - 17 = \frac{\lambda}{2}$

$\lambda = 68$ cm

$v = f\lambda = 512 \times 0.68 = 348$ m/s

Water reservoir was moved downward to get 2[nd] resonance

13. Second resonance during

Winter = 54 cm

But during summer speed of sound increase $\left(v = \sqrt{\frac{\gamma RT}{M}}\right)$

$\because v = f\lambda$

$v \propto \lambda$

So second resonance during

Summer x > 54 cm

14. $v = 2f(\ell_2 - \ell_1)$

$v = 2 \times 480 \times (70 - 30) \times 10^{-2}$

$v = 960 \times 40 \times 10^{-2}$

$v = 38400 \times 10^{-2}$ m/s

$v = 384$ m/s

15. d = 6cm, f = 504, v = 336 m/s

e = 0.3d

$\ell + e = \frac{v}{4f} = 16.67$ cm

$\ell = 16.67 - 0.3 \times 6$

$\ell \simeq 14.9$ cm

16. For first resonance

$\ell_1 + e = \frac{\lambda}{4}$

$\lambda = \frac{336}{400} \times 100 \text{ cm} = 84 \text{ cm} \Rightarrow \frac{\lambda}{4} = 21$ cm

e = 21 – 20 = 1 cm

For third resonance

$\ell_3 + e = \frac{5\lambda}{4} = 105 \text{ cm} \Rightarrow \ell_3 = 104$ cm

17. $17 + x = \frac{\lambda}{4}$ ...(1)

$53 + x = \frac{3\lambda}{4}$ ...(2)

(where x = end correction)

$(2) - (1) \Rightarrow \frac{\lambda}{2} = 36 \Rightarrow \lambda = 72$ cm

$\frac{(2)}{(1)} \Rightarrow x = 1$ cm

Third resonance length + x = $\frac{5\lambda}{4}$

Third resonance length = $\frac{5\lambda}{4} - x = \frac{5 \times 72}{4} - 1$

= 89 cm

SPECIFIC HEAT CAPACITY OF A GIVEN (I) SOLID AND (II) LIQUID BY METHOD OF MIXTURES

1. $\Delta Q = mS_1\Delta T_1 = mS_2\Delta T_2$

$$ms(25) = m\frac{s}{2}(\Delta T)$$

$$\Delta T = 50°C$$

2. $m_{ice}L_f = m_bS_b\Delta T$

m_{ice} (80) = (2400) (0.1) (500 - 0)

m_{ice} = 1500 gm = 1.5 kg

3. $Q = m_iL_f + m_wS_w(\Delta T) + m_wL_v + m_as_a(\Delta T)$

from water equivalent concept

$m_as_a = m_ws_w$

$Q = 10\times80+10\times1\times100+10\times540+10\times1\times100$

= 8200 cal

4. Heat released by the steam when it converts to water at 100°C = $1\times2.26\times10^6$ = 2260KJ

Heat given to ice to convert in water at 0°C

= $1\times3.36\times10^5$ = 336 KJ

Heat given to rise temp. 0° to 100°C

= $1\times4.2\times10^3\times100$ = 420 KJ

So for Heat required = Heat given

1504 KJ heat given by the system

2 kg water 100°C

$\downarrow$

x Kg water

(2–x)kg steam

$(2-x)\times2.26\times10^6 = 1504\times10^3$

x = 1335 g water

5. Heat given = Heat taken

(100) (0.1)(T–75) = (100)(0.1)(45) + (170)(1)(45)

10(T – 75) = 450 + 7650 = 8100

T – 75 = 810

T = 885 °C

6. $Q = ms_{ice}\Delta T + mL_F + ms_{water}\Delta T + mL_V$

= (1)(0.5)(10)+(1)(80)+(1)(1)(100) + (1)(540)

= 5 + 80 + 100 + 540 = 725 cal.

or 725 × 4.18 = 3030 joule.

7. 2kg ice at – 20°C + 5 kg water at 20°C

$Q_{gain} = Q_{lost}$

$$2\times\frac{1}{2}\times20 + M\times80 = 5\times1\times20$$

(M = amount of ice melted)

M = 1 kg

Water = 5 + 1 = 6 kg

8. $536\ \text{cal}/g = \dfrac{536\times4.2J}{10^{-3}kg} = 2.25\times10^6$ J/kg

9. Heat given by water 20 °C → 0 °C

$Q_1 = 10\times1\times(20–0) = 200$ cal

Heat required to melt 10 g ice

$Q_2 = mL = 10\times80 = 800$ cal

$Q_1 < Q_2$

Hence complete ice will not melt

∴ equilibrium temperature = 0 °C

10. $\Delta Q = msd\theta$

420 J = 10 g × 4.2 × $d\theta$

$d\theta$ = 10 °C

11. Let specific heat of liquids be S_1 & S_2 respectively so heat gain by 1st = Heat loss by 2nd

$$mS_1(32–20) = mS_2(40–32) \Rightarrow \frac{S_1}{S_2} = \frac{8}{12} = \frac{2}{3}$$

12.

Available Heat	Required Heat
50g water (80°C)	50g ice (0°C)
$ms\Delta\theta \downarrow$ = 4000 cal	$mL \downarrow$ = 4000 cal
50g water (0°C)	50g water (0°C)

Therefore final temperature will be 0°C

Also all ice will melt and final amount of water = 50 + 50 = 100 g

13. **Available heat**

10g water at 50°C

$ms\Delta\theta \downarrow = 10\times1\times50 = 500$ cal

10g water at 0°C

Required heat

10g ice –20°C

$ms\Delta\theta \downarrow = 10 \times 0.5 \times 20 = 100$ cal

10g ice 0°C

$mL \downarrow = 10 \times 80 = 800$ cal

10g water 0°C

$\therefore$ Final temperature = 0°C

so heat utilised to melt the ice is 400 cal

$$\text{Mass of ice melted} = \frac{400}{80} = 5g$$

$\therefore$ Final amount of ice in mixture = 10–5 = 5g

14. **Available heat**

19g water at 30°C

$ms\Delta\theta \downarrow = 19 \times 1 \times 30 = 570$ cal

19g water at 0°C

Required heat

5g ice at –20°C

$ms\Delta\theta \downarrow 5 \times 0.5 \times 20 = 50$ cal

5g ice at 0°C

$mL \downarrow = 5 \times 80 = 400$ cal

5g water at 0°C

As available heat is more than required heat

so $\theta_f \neq 0°C$

$$\Rightarrow \theta_f = \frac{\text{Excess heat}}{\text{Total mass}} = \frac{570 - 450}{19 + 5} = \frac{120}{24} = 5°C$$

15. **Available heat**

5g steam at 100°C

$mL = \downarrow 5 \times 540 = 2700$ cal

5g water at 100°C

Required heat

6g ice at 0°C

$mL \downarrow 6 \times 80 = 480$ cal

6g water at 0°C

$ms\Delta\theta \downarrow 6 \times 1 \times 100 = 600$ cal

6g water at 100°C

As available heat is more than required heat

so final temperature = 100°C

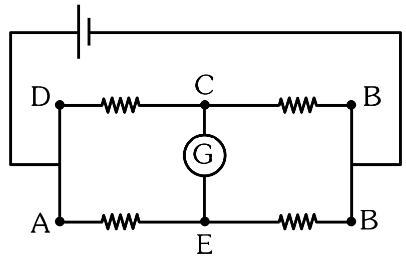
THE RESISTIVITY OF THE MATERIAL OF A GIVEN WIRE USING A METRE BRIDGE

1. At null point deflection through galvanometer is zero, also deflection in galvanometer in opposite direction, either side of null point.

2. Wheat stone bridge is combination of four resistors.

3. Resistivity of material is property of that material only. It does not depend on geometry of material.

4.

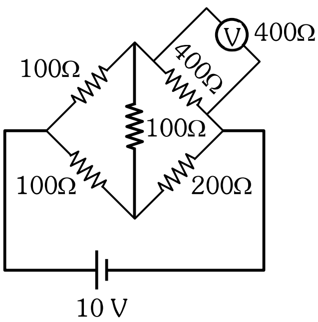


Battery connected across BD

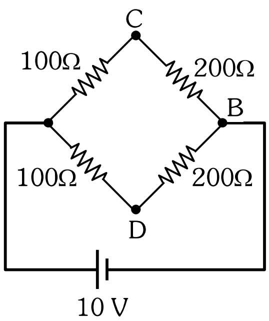
Galvanometer connected across EC

5. $\frac{x}{60} = \frac{12}{40} \Rightarrow x = 18\Omega$

6.



$\Rightarrow$



$v_{CB} = \frac{10}{150} \times 200 = \frac{20}{3}$ volt

7. $\frac{P}{40} = \frac{Q}{60} \Rightarrow P = \frac{2}{3}Q$

$\frac{P}{50} = \frac{\frac{Q \times 50}{Q + 50}}{50} \Rightarrow P = \frac{50Q}{50 + Q}$

$\Rightarrow \frac{50Q}{50 + Q} = \frac{2}{3}Q$

$150 = 100 + 2Q \Rightarrow Q = 25\Omega,\ P = \frac{50}{3}\Omega$

8. Open key $\Rightarrow$ current will not pass, hence act as infinite resistance.

9. Initially

$\frac{R_1}{R_2} = \frac{x}{(1-x)} = \frac{10}{30} \Rightarrow \quad x = 25$ cm

Finally after interchange

$\frac{y}{1-y} = \frac{30}{10} \Rightarrow y = 75$ cm

shifting = 50 cm

10. If radius of wire is doubled then resistance becomes 1/4 times but ratio of AC : CB remains same.

11. $\frac{R_1 + 10}{R_2} = \frac{50}{50} = 1 \Rightarrow \quad R_1 + 10 = R_2 \qquad$ ....(i)

$\frac{R_1}{R_2} = \frac{40}{60} \qquad \Rightarrow \quad 3R_1 = 2R_2 \qquad$ ....(ii)

$R_1 + 10 = \frac{3}{2}R_1 \Rightarrow \quad R_1 = 20\ \Omega$

12. $\frac{5}{R} = \frac{\ell_1}{100 - \ell_1}$ and $\frac{5}{R/2} = \frac{1.6\ell_1}{100 - 1.6\ell_1}$

$\Rightarrow \ R = 15\Omega$

13. Interchanging cell and galvanometer do not effect balance condition.

14. Wire of meter bridge should have high resistivity and low temperature coefficient.

15. To reduces systematic error as well as random error.

16. Average value of 1[st] three measurement is 2.77Ω. So, this can be taken as true value.

17. $\frac{x}{20} = \frac{y}{80} \qquad$ ...(1)

$\frac{4x}{\ell} = \frac{y}{100 - \ell} \qquad$ ...(2)

$\Rightarrow \ \ell = 100 - \ell$

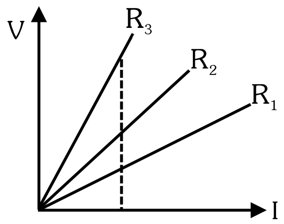
$\Rightarrow \ \ell = 50$ cm

18. $\frac{X}{52 + 1} = \frac{10}{48 + 2} \Rightarrow X = 10.6\ \Omega$

THE RESISTANCE OF A GIVEN WIRE USING OHM'S LAW

1. Ammeter should be connected in series and voltmeter should be connected in parallel.

2.



V = IR

for I = const. $\Rightarrow V \propto R$

Clearly, $R_3 > R_2 > R_1$

3. V = iR

$\Rightarrow$ R $\Rightarrow$ Double $\Rightarrow$ Current will reduce to half.

4. V = IR

$I \propto V$

5. For the validation of ohm's law temperature must be kept constant.

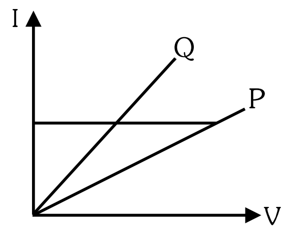
6. V = iR

$R = \frac{60}{4} = 15\Omega$

Again V = iR

$i = \frac{V}{R} = \frac{127.5}{15} = 8.5A$

7.



V = iR

i = const. $\Rightarrow V \propto R$

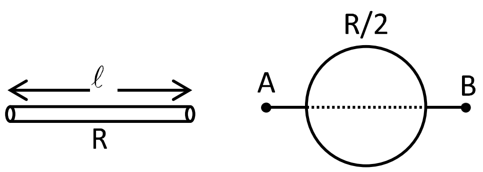
$R_P > R_Q$

8. V = iR $\Rightarrow$ Curve between current voltage graph is straight line.

9. Ammeter should be connected in series with circuit.

10. Si unit of electrical conductance is siemens.

11.



$\Rightarrow$ A—[$\ell/2$]—B (R/2 above, R/2 below) $\Rightarrow R_{eq} = \frac{R}{4}$

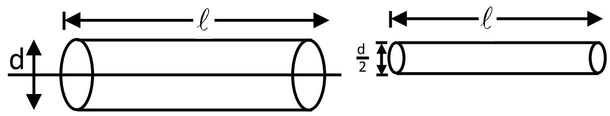
12. Material same $\Rightarrow \rho$ unchanged

$R = \frac{\rho\ell}{A} = \frac{\rho\ell}{\pi a^2} \Rightarrow R \propto \frac{\ell}{a^2}$

Therefore $R' \propto \frac{2\ell}{(2a)^2}$

$\Rightarrow R' = \frac{R}{2}$

13.



Initial volume = final volume

$\frac{\pi d^2\ell}{4} = \frac{\pi d^2 L}{16}$ $\boxed{L = 4\ell}$ $A_f = \frac{A_i}{4}$

$R_i = \frac{\rho\ell}{A_i}$ $R_f = \rho\left(\frac{4\ell}{\frac{A_i}{4}}\right) = 16\,R_i$

14. $\rho = \frac{1}{\sigma} \Rightarrow \rho \times \sigma = \text{constant}$

15. Volume remains same $\Rightarrow$ AL = A'(2L)

$A' = \frac{A}{2}$; $R_i = \frac{\rho L}{A}$

$R_f = \frac{\rho(2L)}{(A/2)} = 4R_i$

$\%\text{change} = \frac{4R_i - R_i}{R_i} \times 100 = 300\%$

16. For I – V curve

$\text{slope} = \frac{I}{V} = \frac{1}{R}$

$R = \frac{1}{\text{slope}}$

$\because R_2 > R_1 \;\; \therefore T_2 > T_1$

17. V = iR

$3 = 3 \times R \Rightarrow R = 1\Omega$

RESISTANCE AND FIGURE OF MERIT OF A GALVANOMETER BY HALF DEFLECTION METHOD

1. Galvanometer is used to defect electric current.

4. $i_g = \frac{150}{10} = 15\text{mA},\ v_g = \frac{150}{2} = 75\text{mV}$

$R_g = \frac{v_g}{i_g} = \frac{75\text{mA}}{15\text{mA}} = 5\Omega$

$R = \frac{v}{i_g} - G = \frac{150}{15\times10^{-3}} - 5 = 9995\Omega$

5. $(i - i_g)S = i_g R_g$

$(1 - 10^{-3})S = 10^{-3} \times 200$

$S = 2 \times 10^{-1}\ \Omega$

6. $i_g = 100\ \mu A = 10^{-4}$ A, $R_g = 100\Omega$, $S = 0.1\ \Omega$

$(i - i_g)S = i_g R_g$

$i = \frac{(R_g + S)i_g}{S} = \frac{(100+0.1)\times10^{-4}}{0.1} = 100.1\text{ mA}$

7. $V = i_g G$

$nV = i_g (R+G) \Rightarrow ni_g G = i_g (R + G)$

$R + G = nG$

$R = G(n - 1)$

8. $i_g = 25 \times 4 \times 10^{-4}\text{ A} = 10^{-2}\text{ A}$

$R_g = 100\ \Omega$

$V = i_g(R_g + R)$

$2.5 = 10^{-2}(100 + R) \Rightarrow R = 150\Omega$

9. $V = i_g(R + R_g)$

$15 = 15 \times 10^{-3}(R + 200) \Rightarrow R = 800\ \Omega$

10. $R_g = 50\Omega,\ i_g = 0.05A$

$(I - i_g)S = i_g R_g$

$S = \frac{50\times0.05}{5} = 0.5\Omega$

$S = \frac{\rho\ell}{A} \Rightarrow \ell = \frac{SA}{\rho} = \frac{0.5\times2.97\times10^{-2}\times10^{-4}}{5\times10^{-7}} \simeq 3\text{m}$

11. $(0.1 + R) \times 5 = 10$

$R = 1.9\Omega$

12. $Si = \frac{1}{K}$

13. $R = Rg\ (n - 1)$

$n = \frac{V}{V_g} = \frac{10}{50\times10^{-6}\times100} = 2000$

$R = 100 \times (2000 - 1) = 199.9\text{k}\Omega$

$\simeq 200\text{ k}\Omega$

14. $\frac{\theta}{i} = \frac{50}{10^{-3}} = 5000,\ \frac{\theta}{V} = 20$

$\Rightarrow \frac{\theta/i}{\theta/V} = \frac{5000}{10} = 250 \Rightarrow \frac{V}{i} = R = 250\Omega$

15. $i_1 = \frac{E}{R+G}\quad i_2 = \frac{E}{R + \frac{GS}{G+S}} = \frac{E(G+S)}{RG+RS+GS}$

$\frac{i_1}{2}G = \left(i_2 - \frac{i_1}{2}\right)S$

$\frac{i_1}{2}(G+S) = \frac{E(G+S)}{RG+RS+GS}\cdot S$

$\frac{1}{2(R+G)} = \frac{S}{RG+RS+GS}$

$2RS + 2SG = RG + RS + GS$

$RS + GS = RG$

$S(R + G) = RG$

FOCAL LENGTH OF CONCAVE MIRROR, CONVEX MIRROR & CONVEX LENS

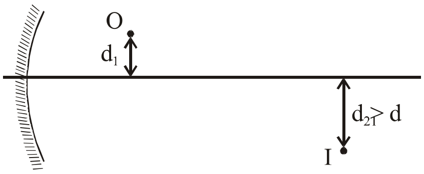
5. from displacement method

$d \geq 4f \qquad \therefore \frac{d}{4} \geq f$

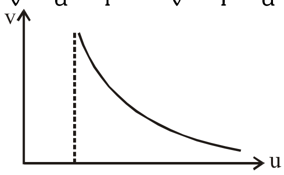
6. Spherometer is used to measure radius of curvature of the curved surface.

7. $m = \frac{h_i}{h_0} = -\frac{d_2}{d_1}; |m| > 1$

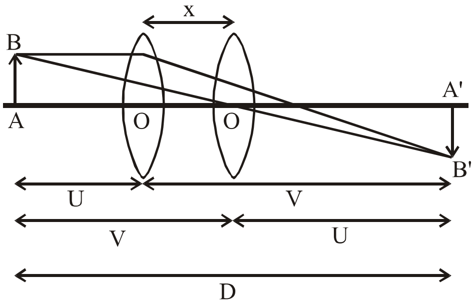
$|m| = \left|-\frac{v}{u}\right| > 1 \Rightarrow |v| > |u|$



8. $\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{v} = \frac{1}{f} - \frac{1}{u} \Rightarrow v = \frac{fu}{u-f}$



9.



$m_1 = \frac{V}{U}, m_2 = \frac{U}{V}$ (V & U interchange value between the object & screen)

$m_1 - m_2 = \frac{V}{U} - \frac{U}{V}$

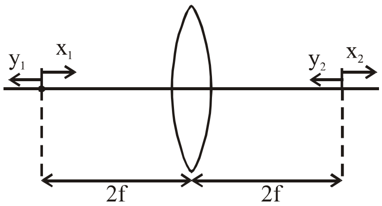
$m_1 - m_2 = \frac{V^2 - U^2}{UV} = \frac{(V-U)(V+U)}{UV}$

Now $V - U = X$, $\frac{1}{f} = \frac{1}{V} - \frac{1}{(-V)}$

$\frac{1}{f} = \frac{U+V}{UV}$

$\therefore m_1 - m_2 = \frac{x}{f} \Rightarrow f = \frac{X}{m_1 - m_2}$

10.



$\frac{\text{displacement of image}}{\text{displacement of object}} = \left(\frac{\text{position of image}}{\text{position of object}}\right)^2$

14. $u = -25$ cm, $v = +15$

$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

by solving $f = \frac{75}{2}$, $\Rightarrow R = 75$ cm

THE PLOT OF THE ANGLE OF DEVIATION VS ANGLE OF INCIDENCE FOR A TRIANGULAR PRISM

3. $\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$

When μ is increased δ_m will also increase, hence the deviation will also increase.

4. When light rays deviation by prism is minimum, then angle of incident and emergence are equal.

6. $\angle i = 38°, \angle e = 58°, \delta = 50°$

$\because \delta = i + e - A \Rightarrow \qquad A = 46°$

7. $\angle A = 90°, \angle i = 45°, \angle e = 60°$

$\because \delta = i + e - A = 15°$

8. If ray passes parallel to the base then

$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)} \qquad \delta_m = 2i - A$

REFRACTIVE INDEX OF A GLASS SLAB USING A TRAVELLING MICROSCOPE

7. Movement of microscope = normal shift

$= \left(1 - \frac{1}{\mu}\right)t = \left(1 - \frac{1}{1.5}\right)3$

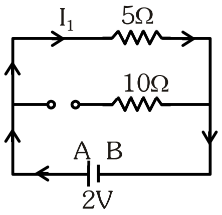
1 cm upwards

10. μ = real depth / apparent depth

$= \frac{C-A}{C-B}$

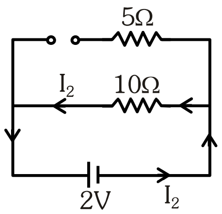
CHARACTERISTIC CURVES OF A P-N JUNCTION DIODE IN FORWARD AND REVERSE BIAS

2. When +ve terminal is connected to A, D_2 is reversed biased & D_1 will forward biased



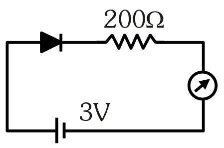
$\therefore I_1 = \frac{2}{5} = 0.4A$

when +ve terminal is connected to B, D_1 is reversed biased and D_2 is forward biased



$\therefore I_2 = \frac{2}{10} = 0.2A$

7.



Silicon diode is in forward bias.

Hence across diode potential barrier

$\Delta V = 0.7$ volts

$$I = \frac{V - \Delta V}{R} = \frac{3 - 0.7}{200}$$

$$= \frac{2.3}{200} = 11.5 \text{ mA}$$

8. Initially Ge & Si are both forward biased so current will effectively pass through Ge diode with a drop of 0.3 V, then $V_0 = 12 - 0.3 = 11.7$ V

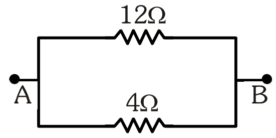
if "Ge" is reversed then current will flow through "Si" diode, then $V_0 = 12 - 0.7 = 11.3$ V.

Therefore $|\Delta V_0| = 0.4$ V.

9. $I = \frac{6}{300} = 0.02$ (D_2 is in reverse bias)

11. (i) $V_A > V_B \Rightarrow$ diode is in FB

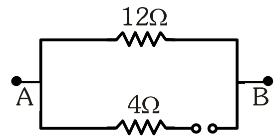
$\Rightarrow$



$\Rightarrow R_{AB} = 3\Omega$

(ii) $V_A < V_B \Rightarrow$ diode is in RB

$\Rightarrow$



$\Rightarrow R_{AB} = 12\Omega$

19. $R_{dy} = \frac{\Delta V}{\Delta i} = \frac{0.2}{(10-5)\times 10^{-3}}$

$= 0.2 \times 0.2 \times 10^3$

$= 40\Omega$

CHARACTERISTIC CURVES OF A ZENER DIODE AND FINDING REVERSE BREAK DOWN VOLTAGE

3. Zener diode is heaving doped, so at small thickness of depletion region provides required zener break down voltage or field $\left(E = \frac{V}{d}\right)$

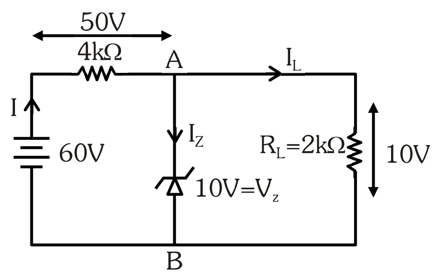
5. Voltage across zener diode = constant

$\therefore \quad V_{R_L} = $ const. $\Rightarrow I_L = $ const.

so, if $V_{in} \uparrow$, V_{R1} increases

$\therefore \quad I\uparrow, I_Z\uparrow \; (\because I_Z = I - I_L)$

6. $\therefore \quad I = \frac{50}{4} = 12.5$ mA

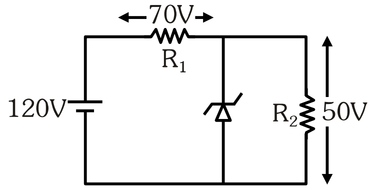


$\Rightarrow \quad I_L = \frac{10}{2} = 5\text{mA}$

$\therefore \; I_Z = 12.5 - 5 = 7.5$ mA

8. Assuming zener diode does not undergo breakdown, current in circuit $= \dfrac{120}{15000} = 8\,\text{mA}$

$\therefore$ Voltage drop across diode = 80 V > 50 V.
The diode undergo breakdown.



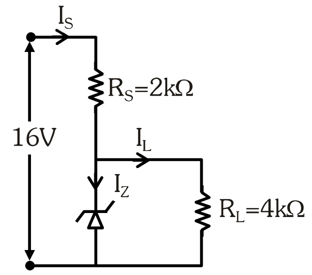
Current is $R_1 = \dfrac{70}{5000} = 14\,\text{mA}$

Current is $R_2 = \dfrac{50}{10000} = 5\,\text{mA}$

$\therefore$ Current through diode = 9mA

9. Since voltage across zener diode must be less than 10V therefore it will not work in breakdown region, & its resistance will be infinite & current through it is equal to zero.

10. Maximum current will flow from zener if input voltage is maximum.



When zener diode works in breakdown state, voltage across the zener will remain same.

$\therefore$ V_{across} 4kΩ = 6V

$\therefore$ Current through 4kΩ $= \dfrac{6}{4000}\text{A} = \dfrac{6}{4}\text{mA}$

Since input voltage = 16V

$\therefore$ Potential difference across 2kΩ = 10V

$\therefore$ Current through 2kΩ $= \dfrac{10}{2000} = 5\text{mA}$

$\therefore$ Current through zener diode
$= (I_S - I_L) = 3.5$ mA

11. Zener diode is heavily doped and have narrow depletion layer.

12. $i = \dfrac{20V - 15V}{10k\Omega} = 0.5$ mA

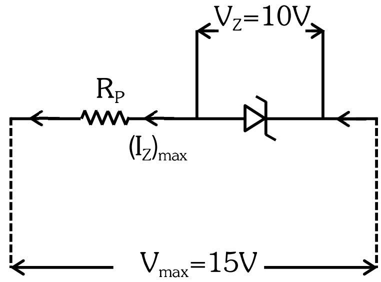
as first zener diode is forward biased.

13. Reverse bias Zener diode is used a voltage regulator

for Ge Potential barrier V_0 = 0.3 V
Si Potential barrier V_0 = 0.7 V

14. For zener diode $\rightarrow$ Doping is high
& Depletion region is thin
& It is operated in Reverse Bias region
& Zener voltage (V_z) is constant

20.



$V_{max} = V_Z + {}_{max}(I_Z)\,(R_P)$

$15 = 10 + (I_Z)_{max}\,(R_P)$ ...(1)

$\because$ $(\text{Power})_{max} = 0.4 = (V_Z)\,(I_Z)_{max}$

$$\frac{0.4}{10} = (I_Z)_{max} \qquad \text{... (2)}$$

then from eq. (1) & (2)

$$R_P = \frac{(15-10)}{(I_Z)} = \frac{(5)}{(0.04)}$$

$\boxed{R_P = 125\Omega}$

IDENTIFICATION OF DIODE LED, RESISTOR A CAPACITOR FROM A MIXED COLLECTION OF SUCH ITEMS

1. In forward bias diode conducts

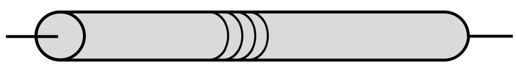
In reverse bias it does not conducts.

2. $R = (47 \pm 4.7) \times 10^3$

As per colour code, 4 - Yellow, 7 - Violet, 3 - Orange, 10% - Silver

3. $R = 47 \times 10^1 \pm 5\% = 470\ \Omega,\ 5\%$

4.



OBYG

	B	B	R	O	Y	G	B	V	G	W
	0	1	2	3	4	5	6	7	8	9
Multiplier	1	10	10^2	10^3	10^4	10^5	10^6	10^7	10^8	10^9

Tolerance (%) : Gold, Silver, None
5 10 20

(360 ± 18) kΩ